A MANUAL OF THE GEOLOGY OF INDIA AND BURMA

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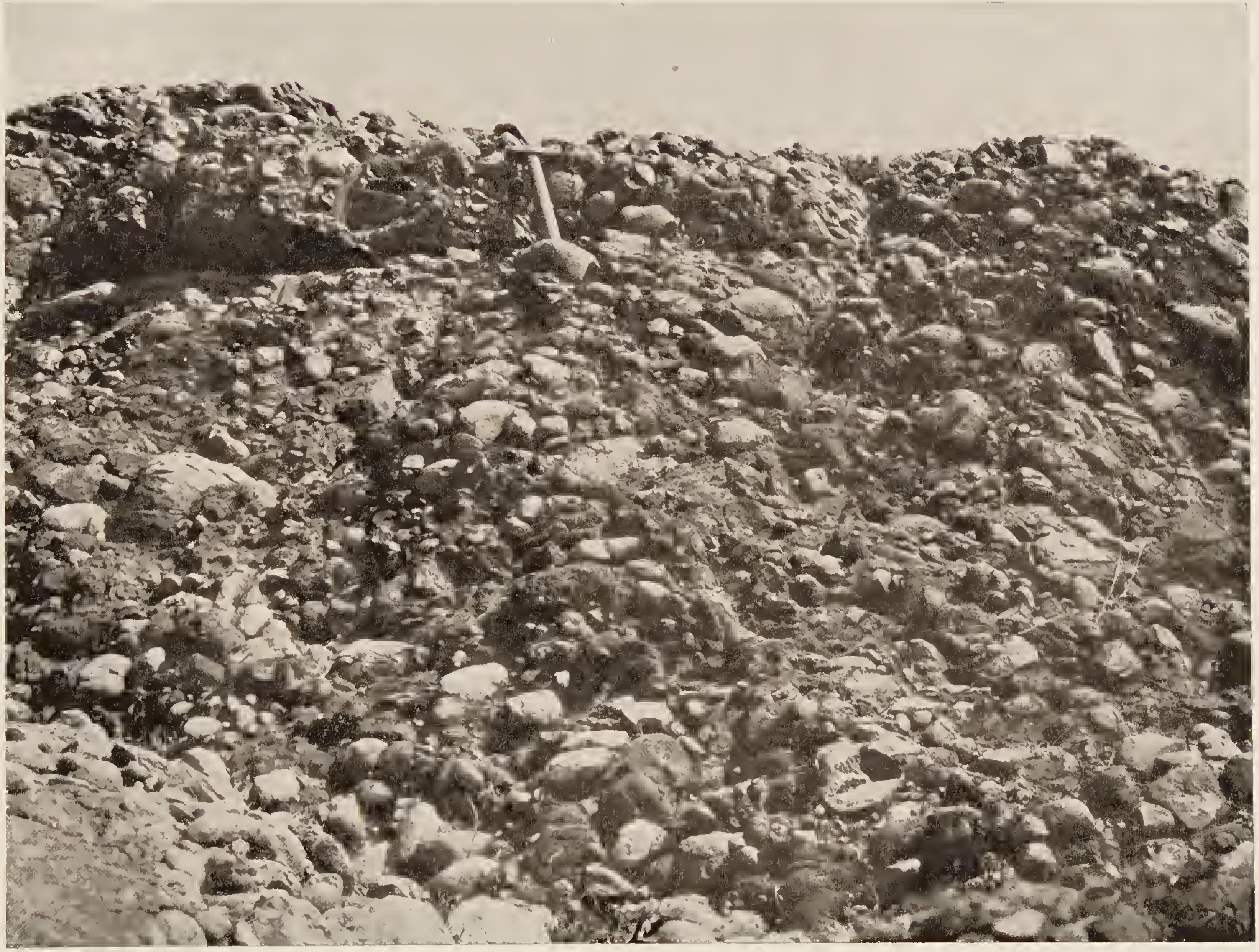
IN FOUR VOLUMES
VOLUME II



BASAL CONGLOMERATE OF DELHI SYSTEM.

B. C. Gupta, photo.

G. S. I., Calcutta.

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A MANUAL
OF
THE GEOLOGY OF INDIA AND BURMA

VOL. II

Compiled from the observations of the Geological Survey of India and from unofficial sources by H. B. MEDLICOTT, W. T. BLANFORD, V. BALL and F. R. MALLET.

Second Edition by R. D. OLDHAM

Third Edition, revised and largely rewritten

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1851

Published by order of the Government of India.

PRINTED IN INDIA, BY THE MANAGER, GOVERNMENT OF INDIA PRESS, CALCUTTA, AND PUBLISHED BY THE MANAGER OF PUBLICATIONS, CIVIL LINES, DELHI, 1959.

Price : Rs. 26·00 or 40 sh.

FOREWORD

The First Volume of this Manual was published in 1950, but various unavoidable and unforeseen difficulties have hitherto prevented the publication of the subsequent volumes. In presenting the Second Volume, I would like to add that every effort is being made to bring out the Third Volume more expeditiously.

After the manuscript of the Manual was completed by the late Sir Edwin Pascoe, the geology of many parts of India has been revised on more modern maps and on aerial photographs, several investigations have been carried out afresh and new mineral bearing zones have been discovered. No attempt has, however, been made to incorporate the results of these later investigations in the present edition which is essentially the same as was originally written up by the late Sir Edwin Pascoe.

B. C. ROY,
DIRECTOR,
Geological Survey of India.

CALCUTTA,
The 26th March, 1959.

Please see CORRIGENDA at the end.

PREFACE TO THE THIRD EDITION.

The First Edition of this Manual was issued in 1879, and the Second fourteen years later in 1893. The latter was compiled before the microscope came into prominent use for petrological purposes, and no edition has appeared since. The present edition, long overdue, embodies more than fifty years' additional work, not only by the largely increased staff of the Geological Survey of India but also by many unofficial investigators. The colossal size of the task of co-ordinating all this accumulation of work must be my plea for some at least of the shortcomings and omissions that seem almost inevitable.

Certain portions of the text of the Second Edition have been incorporated with but slight modification, but the bulk of the present edition is entirely new. An attempt has been made to render it more a work of reference than a students' text-book, since the latter is available in the form of Mr. D. N. Wadia's excellent and well-known publication. An attempt to cater for the local geologist in India has played its part in swelling the volume of the work. This edition of the Manual makes no pretence of being more than it is— a compilation of the writings, mostly published, of a large band of workers, to all of which it would be a pleasure to pay tribute by name, did space permit. One of the effects of a wise system of Mining Regulations has been to encourage unofficial geological investigation in India and Burma, and oil companies and companies engaged in the exploitation of other minerals have for a long time past employed their own geological staffs for exploratory purposes, and many valuable papers have issued from the pens of such men as Mr. E. S. Pinfold, Mr. P. Evans, Dr. F. G. Percival and Dr. A. W. G. Bleeck. In addition, a large number of academical workers have visited India and Burma from time to time, some of them for lengthy periods, and have made contributions to our knowledge of the subject in the Memoirs and Records of the Geological Survey of India, in the Transactions of the Mining and Geological Institute of India, and in other publications too numerous to mention. Dr. W. F. Smeeth and his colleagues in the Mysore Geological Department have in many ways modified our conceptions of the Archæan of Southern India. Dr. L. Dudley Stamp, at one time Professor in Rangoon University, has contributed many original ideas on the Tertiary geology of Burma. Colonel L. M. Davies, by combining geological field-work with his military duties, has added considerably to our knowledge of the Eocene rocks of the North-West-Frontier. Numerous eminent American authorities, among whom may be mentioned Dr. W. D. Matthew, Dr. H. de Terra, Dr. G. E. Lewis, Dr. Barnum Brown and Dr. Colbert, together with a French geologist, M. L'Abbe' T. de Chardin of the Geological Survey of China, have made the study of Siwalik vertebrates and stratigraphy peculiarly their own; their numerous published contributions to this subject have been freely consulted and used. The Italian expeditions to Kashmir and the Karakoram, and the various climbing parties, especially those to Mount Everest, have discovered many new facts and produced many new suggestions concerning the Extra-peninsular regions. One of the latest of these is a memoir by Messrs. Arnold Heim and Gansser, containing some important deductions connected with Himalayan stratigraphy. Mr. Pinfold's prolonged work on the oilfields of the Punjab has done much to assist in our correlation of the Eocene. Mr. P. Evans' survey of Assam has laid the foundations of a proper consecutive classification of the Tertiaries in that somewhat neglected province; only those who have suffered from its enervating and not too healthy climate, the denseness of its jungles and the frequent dearth of exposures, can appraise to the full the value of such an accomplishment. Among the many distinguished palæontologists who have from time to time lent us their valuable assistance, the two most prominent names are those of Dr. Cowper Reed of Cambridge and Dr. L. F. Spath of the Natural History Museum, South Kensington. The former has been associated with the Geological Survey of India for so many years and has contributed so many valuable memoirs to the "Palæontologia Indica", that he is justly esteemed by all officers of the department as the *doyen* of Indian palæontology. Dr. Spath's monumental works on the ammonite faunas of India have also left us in his debt to an extent which it would be difficult to exaggerate. In addition, we may pay grateful tribute to such well-known names as J. W. Gregory, F. L. Kitchin, P. Martin Duncan, W. P. Sladen, C. Diener, E. von Mojsisovics, A. Bittner, V. Uhlig, K. Redlich, R. Zeiller, Sir Albert Seward, Sir Arthur Smith Woodward, B. Sahni, Miss E. Healy, M. Cossmann, G. Pissaro, S. S. Buckman, H. Douville, E. Spengler, C. Forster Cooper, L. R. Cox, Miss H. M. Muir-Wood, W. L. F. Nuttall, C. A. Matley, L. Rama Rao, J. Pia, J. A. Douglas and W. B. R. King.

To my colleagues of the Geological Survey of India I am indebted, not only for the innumerable published papers which have furnished the foundations of this book, but for more direct help in criticism and suggestions regarding the text itself. Especially have I to thank Dr. J. Coggin Brown, whose unstinted assistance has done much to improve the accuracy and complete the scope of the chapters on Burma : his unrivalled knowledge of the geology of that former province of the Indian Empire has been generously and unreservedly placed at my disposal. The chapters on the Upper Tertiary are greatly the better for the expert scrutiny of my colleague Dr. G. E. Pilgrim, to whose ungrudging help I gratefully testify. To Sir Lewis Fermor, Dr. A. M. Heron, Dr. J. A. Dunn and Dr. W. D. West I am deeply indebted for opinions and criticism concerning the chapters on the Archæan. To Dr. W. D. West, and Messrs. J. B, Auden and D. N. Wadia I am grateful for help in connection with Himalayan stratigraphy and tectonics. I have also received much assistance from Mr. E. R. Gee upon the stratigraphy of the Salt Range, from Dr. H. Crookshank upon the Deccan Trap, and from Dr. M. R. Sahni concerning fossil nomenclature. Dr. B. Sahni's publications on Gondwana plants have formed the basis of much of the text on this subject. Dr. J. A. Dunn has been kind enough to revise the chapter on the Archæan of Singhbhum in the light of some very recent discoveries of his own—discoveries which have removed some deep misgivings in my own mind concerning some of the statements previously published regarding the rock relationships of that region. To Dr. A. L. Coulson I am indebted for suggestions regarding the chapters on Rajputana and the section on the Cuddapah rocks of Madras. To Dr. M. S. Krishnan I owe acknowledgement for general help as well as for suggestions in connection with the geology of Gangpur and neighbouring parts. I thankfully acknowledge assistance from Dr. L. F. Spath of the Natural History Museum, South Kensington, regarding the ammonites and classification of the Lower Trias, and from Colonel L. M. Davies for corrections and suggestions concerning the text dealing with the Palæocene and Eocene. Finally, I must not omit to acknowledge the constant help derived from Sir Thomas Holland's memoir on Indian Geological Terminology (Mem. LI, Pt. 1, 1928), which with few exceptions has been followed, and from Mr. La Touche's various indexes.

In a book of this kind it is sometimes difficult to decide to what extent it is justifiable to allow one's views to outweigh those of others. Two alternative methods of procedure present themselves in the very numerous cases where doubt exists as to the precise conclusion to be drawn from the available evidence. On the one hand, the author can select the view which in his judgment deserves support and adopt it, with or without a word of caution to the reader : on the other hand, he may choose to lay the facts as fully as space permits before the reader and leave him to make his own conclusions. The former is the one adopted by most text-books, since condensation demands it, the result often being a too definite picture which has earned the term of "text-booky". At the same time, the second method leads to greater prolixity and to a less connected and less readable story. In this work I have attempted a compromise between the two, reverting more often perhaps than the majority of text-book writers to the second method.

For the constant repetitions in the text I feel no apology is necessary. They have been allowed to remain for what is often referred to in correspondence of an official nature as "easy reference". Chapter headings have given some trouble but I have chosen the terminology of the European sequence even when the correlation is doubtful or not completely dimensional, rather than the use of local names which would mean nothing to readers unacquainted with Indian geological formations. The use of capital letters will more or less explain itself. As examples, "Deccan Trap", so written, is a suite of rocks including ashes and other forms of volcanic material as well as inter-trappean sedimentaries belonging to that suite. "Deccan Trap" is a trap rock belonging to the Deccan Trap suite. "Berach granite" is a Granite found in the Berach river. "Bundelkhand Granite" is a granitic suite with a definite systematic position.

To facilitate their location, the latitude and longitude of all lesser-known places will be found after their names in the index at the end of the book. The spelling of names, always a difficulty in countries using an alphabet different from that employed by most European nations, is in nearly all cases that adopted as a standard by modern official gazetteers ; as regards place names not mentioned in those publications, the spelling used is that on the latest maps of the Survey of India where these are available. Where advisable, obsolete or alternative spellings are given in brackets. Where an Indian place name has been used to distinguish a geological formation, it has been the custom of the Geological Survey of India to adopt the spelling used by the donor of the name to the formation, whether it conforms to the gazetteer spelling or not. This leads sometimes to different ways of spelling the same word but, although the artificiality of such a convention grates somewhat on the senses and although the risk of ambiguity is not entirely removed by its use, the practice has been followed in this work, in order to avoid what might result in still worse confusion. The spelling of the names of geological subdivisions has, in fact, in nearly all cases been that adopted in Sir Thomas Holland's "Indian Geological Terminology", published as Part I, Volume LI. of the Memoirs of the Geological Survey of India.

The geological map accompanying this text has been compiled, with a few corrections, from the fifth edition of the 32-mile map published by the Geological Survey of India in 1928. The preparation of the text-figures and plates has been kindly superintended by Dr. Coulson and later by Dr. West and Dr. P. K. Ghosh to whom I am further indebted for this assistance as well as for much laborious work connected with the printing.

Earthquakes have been discussed in so far as they throw light on tectonic problems. Mineral springs, of which India can boast a large number, have received brief attention, but a description of Indian meteorites, of which an unusually fine collection may be found in the Indian Museum in Calcutta, has been omitted as being outside the terms of reference.

I have taken the liberty of using the words "mylonise" and "mylonisation" instead of mylonitise and mylonitisation, on the grounds that the noun mylonite is subordinate to the verb expressing the process which produced it.

EDWIN H. PASCOE,
"Fallows Green House",
Harpenden.
27th January, 1939.

The war of 1939 commenced when the work was nearing completion and had reached the revision stage. Final revision has, in consequence, been carried out under great difficulties. In spite of the fact that more than half of the book had been set up in type when Japan entered the war, its publication had to be postponed on account of paper shortage. The type — $2\frac{1}{2}$ tons of metal — was broken and melted for munitions purposes. The evacuation of libraries from London, difficulties in travelling facilities and other factors resulting from war conditions have made it impossible to bring the text completely up to date ; nevertheless, some additions and a few modifications have been attempted.

EDWIN H. PASCOE,
"Fallows Green House",
Harpenden.
19th August, 1944.

I am sincerely grateful to the Burmah Oil Co., and more specifically to their Chief Geologist, Mr. P. Evans, for much valuable assistance in bringing up to date the Tertiary portion of the geological map published with this work.

EDWIN H. PASCOE,
"St. Nicholas' Lodge",
Harpenden.
12th February, 1949.

THE LATE SIR EDWIN PASCOE

It is with great regret that I have to record the death of Sir Edwin Pascoe on the 7th July, 1949 before the first volume of this work could be issued from the press.

Sir Edwin began the task of writing the third edition of the Manual in 1933. After devoting seven years to the work, he finally submitted the manuscript of the three volumes at the end of 1939. Unfortunately the extreme shortage of paper in India during the war made it impossible to print even the first volume, although it had been set up in type. The type was distributed and it was not until the end of 1945 that the press could once again take up the work. In the interval Sir Edwin thoroughly revised the text of volumes I and II, corrected all the proofs of volume I, and had completed the correction of the galley proofs of volume II when he was taken seriously ill.

Volume III, still in manuscript, was only partly revised. It is considered, however, that it will be best to publish it as he left it, and it will be sent to the press without further revision. Volume IV, consisting of general and geographical indexes, was started by Sir Edwin, but no trace of it could be found after his death.

Though Sir Edwin did not live to see the publication of his great work, it will long remain a testimony to the industry and scholarship that he devoted to its making over a period of 16 years.

W. D. WEST,

Director,

Geological Survey of India.

CALCUTTA,

The 28th October, 1949

LIST OF ABBREVIATIONS.

Mem.—Memoirs of the Geological Survey of India.
Rec.—Records of the Geological Survey of India.
J.A.S.B.—Journal of the Asiatic Society of Bengal.
Q.J.G.S.—Quarterly Journal of the Geological Society of London.
Man., 2nd Edit.—Manual of the Geology of India, Second Edition.
Gen. Rep.—General Report of the Geological Survey of India.
Ann. Rep.—Annual Report of the Geological Survey of India.
Pal. Ind. Ser. and New Ser.—Palaeontologia Indica, Series and New Series.

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(3) *Oryctocephalus salteri* Reed (×6) (*Pal. Ind.*. Ser., XV, vol. VII).
(4) *Ptychoparia spitiensis* Reed (×2½) (*Pal. Ind.*, Ser. XV, vol. VII).
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(6) *Anomocare hundwarense* Reed (×6) (*Pal. Ind.*, New Ser. XXI, No. 2).
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(11) *Acrothele prœstans* Reed (pedicle valve. ×4) (*Pal. Ind.*, Ser. XV, Vol. VII).
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(8) *Leptœna trachealis* (Salter) (×5) (*Pal. Ind.*, Ser. XV, Vol. VII, Mem. 2).
(9) *Pterinaea thanamensis* Reed (×2) (*Pal. Ind.*, Ser. XV, Vol. VII, Mem. 2).
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(6) *Halysites catenularia* var. *kanaurensis* Reed (×¾).
(7) *Leptaena rhomboidalis* Wilckens. (×2).
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(3) *Hemitrypa oculata* Phillips (×10) (*Pal. Ind.*, New Ser. II, Mem. 5).
(4) *Polypora hudlestoni* Reed (×1¼) (*Pal. Ind.*, New Ser. Vol. VI, Mem. 2).
(5) *Cyathophyllum (Thamnophyllum) multizonatum* Reed (×1½) (*Pal. Ind.*, New Ser. Vol. VI, Mem. 2).
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(7) *Calceola sandalina* Lamarck (×1½) (*Pal. Ind.*, New Ser. II, Mem. 5).
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b. basal plates a. anal plate
r. radial plates a t. anal tube
ra. radianal plate
(10) *Uncinulus* var. *transiens* Reed (×1¼) (*Pal. Ind.*, New Ser. VI, Mem. 2).
(11) *Atrypa spinosa* Hall var. *chitralensis* Reed (×2) (*Pal. Ind.*, New Ser. VI, Mem. 2).
(12) *Spirifer verneuili* Murchison (×1½) (*Pal. Ind.*, New Ser. VI, Mem. 2).
(13) *Chonetes subcancellata* Reed (×2½) (*Pal. Ind.*, New Ser. II, Mem. 5).
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(4) *Dielasma lidarense* Dien. (×1) (*Pal. Ind.*, New Ser. V, Mem. 2).
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(7) *Conularia punjabica* Reed (×2) (*Pal. Ind.*, New Ser. XXIII, Mem. 1).

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(1) *Streptorhynchus* (*Schuchertella*) *purdoni* Reed (×2).
(2) *Productus* (*Dictyoclostus*) *Genuinus* Kutorga (×1).
(3) (a) *Marginifera himalayensis* Dien. 3a : dorsal view }(×1).
(b) *Marginifera himalayensis* Dien. 3b : apical view }
(4) *Chonetes* (*Plicochonetes*) *simulata* Reed (×2).
(5) *Rhynchopora ? complanata* Reed (×2½).
(6) *Dielasma truncatum* Waag. (×1).
(7) *Notothyris inaequiplicata* Reed (×2).
(8) *Spirifer* (*Purdonella*) *conformis* Reed (×1½).
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(10) *Athyris* (*Cleiothyridina*) *interposita* Reed (×2).
(11) *Spirigerella minuta* Waag. (×3).
(12) *Pleurotomaria* (*Phymatopleura*) *uchhaliensis* Reed (×2).
(13) *Macrocheilina* (*Sphaerodoma*) cf. *intercalaris* Meek and Worthen (×½)
(14) *Euomphalus* (*Schizostoma*) *oldhami* Reed (×3).
(15) *Bellerophon equivocalis* Reed (×1½).
(16) (a) } *Xenaspis carbonaria* Waag. (×1).
(b) }

(From 1 to 15—*Pal. Ind.*, New Ser. XXIII, Mem. 2 ; and 16 (a) and (b)—*Pal. Ind.*, Ser. XV, Vol. I).

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(6) *Ceratites wynnei* Waag. (×1) (*Pal. Ind.*, Ser. XIII, Vol. II, pt. 1).
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(8) *Otoceras clivei* Dien. (×1) (*Pal. Ind.*, Ser. XV, Vol. II, pt. 1).

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Triassic Fauna—*contd.*

(9) *Ophiceras sakuntala* Dien. (×1) (*Pal. Ind.*, Ser. XV, Vol. II, pt. 1).
(10) *Sibirites prahlada* Dien. (×1) (*Pal. Ind.*, Ser. XV, Vol. II, pt. 2).
(11) *Ptychites cognatus* Oppel. (×1) (*Pal. Ind.*, Ser. XV, Vol. II, pt. 2).
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(1) *Gangamopteris cyclopteroides*, var. *major* Feistm. (×½) (*Pal. Ind.*, Ser. XII, Vol. III).
(2) *Gangamopteris cyclopteroides*, var. *major* Feistm. (×½) (*Pal. Ind.*, Ser. XII, Vol. III).
(3) *Cordaites* (*Noeggerathiopsis*) *hislopi* (Bunb.) (×½) (*Pal. Ind.*, New Ser. VII, Mem. 1).
(4) *Ottokaria bengalensis* (Zeill) (×1) (*Pal. Ind.*, New Ser. VII, Mem. 1).
(5) *Gondwanidium validum* (Feistm.) (*Pal. Ind.*, Ser. XII, Vol. III).
(6) *Buriadia sewardi* Sahni (*Pal. Ind.*, New Ser. Vol. XI, pt. 1).

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(1) *Glossopteris communis* Feistm. (×⅓ approx.) (*Pal. Ind.*, Ser. XII, Vol. III).
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(5) *Glossopteris browniana* Brong. (*Pal. Ind.*, Ser. XII, Vol. II).
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(1) *Schizoneura gondwanensis* Feistm. (×½) (Mem. LVIII).
(2) Stem of *S. gondwanensis* Feistm. (×½) (Mem. LVIII).
(3) *Phyllotheca indica* Bunb. Feistm. (×½) (Mem. LVIII).
(4) *Sphenophyllum speciosum* (Royle).
(5) *Vertebraria indica* Royle. (×½) (*Pal. Ind.*, Ser. XII, Vol. III).
(6) *Sphenopteris polymorpha* Feistm. (*Pal. Ind.*, Ser. XII, Vol. III).
(7) *Taeniopteris danaeoides* (Royle.).

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Gondwanosaurus bijoriensis Lyd. (×⅓) (*Pal. Ind.*, Ser. IV, Vol. 1, pt. 4).

Panchet and Parsora Fossils. 962

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(3) *Pecopteris concinna* Presl. (×1) (*Pal. Ind.*, Ser. XII, Vol. III).
(4) *Cyclopteris pachyrhachis* Göepp. (×1) (*Pal. Ind.*, Ser. XII, Vol. III).
(5) *Dicroidium* (*Thinnfeldia*) *odontopteroides* (Morr.) (*Pal. Ind.*, Ser. XII, Vol. III).
(6) *Danaeopsis hughesi* Feistm. (×¾) (*Pal. Ind.*, New Ser. VII, Mem. 1).
(7) *Taeniopteris stenoneuron* (Schimp.) (×1) (*Pal. Ind.*, Ser. XII, Vol. III).
(8) *Samaropsis* sp. (×1) (*Pal. Ind.*, Ser. XII, Vol. III).

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A MANUAL
OF THE
GEOLOGY OF INDIA AND BURMA

CHAPTER XIV.

PURANA or EARLY PALÆOZOIC.—THE VINDHYAN SYSTEM, THE KURNOOL SERIES AND OTHER SUPPOSED EQUIVALENTS.

Land barrier between the north and the south. **Kurnool series, Madras.**—General position; Relationships and subdivision; Banganapalli stage; Diamond fields; Jamalamadugu stage; Paniam stage; Kundair stage; The Palnad; A third outlier. **Bhima series of Hyderabad and Southern Bombay.**—Position and relationships; Subdivision; Lower division; Diamond beds; Shale stage; Overlap of the Upper over the Lower division; Upper division; Disturbance; Relationship to the Kurnool. **Godavari and Mahanadi areas**—Uncertain stratigraphical position; **Sullavai series**; Chimur-Mul area.

The Vindhyan system of the northern part of Peninsula.—Subdivision; Position and extent; Conditions of deposition; Age of the system; General lack of disturbance, Localised zones of disturbance. **Lower Vindhyan**: Distribution; General character. (i) **The Son Valley**: Mode of occurrence; Relationship to the Jungel Shales; Sub-division; Thickness and structure; Mode of deposition; Jointing, and sandstone dykes; Basal stage of the West; Basal stage of the East; Porcellanite stage; Kheinjua stage; Rohtas stage. (ii) **Bundelkhand**: Position; Subdivision; Semri Sandstone; Semri Limestone and Shales; Dalchipur stage; Pulkoa Shales and Tirohan Limestone; Tirohan Breccia; Overlap at Karwi; Correlation with the Son valley sequence; Limits of deposition; Folding. (iii) **Saugor District** (iv) **Dhar Forest area and North Bhopal.** (v) **The Chitor-Jhalra Patan area**: Strike; General relationships; Structure; Northern corner of Malwa (North Indore); Nimbahera area. (vi) **Eastern Rajputana**: Mode of occurrence and general character; Base; Tirohan Limestone; Tirohan Breccia; Disappearance southwestwards. (vii) **Lower Vindhyan Basic Dykes. Upper Vindhyan**: Possibly organic impressions; Distribution; Lower boundary; Subdivision; Character and mutual relationships of the subdivision; Kaimur series; Rewah series; Diamonds in the Vindhyans; Bhander series; Bhopal area; Dhar Forest area; Bagh and Jobat; Topography of the Upper Vindhyans. **Trans-Aravalli Vindhyan basin: I. The Malani Granite and Volcanic suite**:—Geological position; Analyses: Mutual relationships; (a) **Malani Granite and its hypabyssal Equivalents—Sirohi State**—Three principal groups—Composition—Porphyry dykes—Quartz veins: **Marwar State**—Two types—Siwana type —Jalor type—Topaz-granite and wolfram-bearing veins of Rewat—**Bikaner**: Isolated tors: **Hissar District, Punjab**—Tusham granite—Porphyritic varieties—Quartz-porphyry dykes—Relationships. (b) **The Malani Volcanics**: Distribution: Salt Range boulder bed; Sirohi State—Trend of the exposures—Jharoli-Ban area—Pamta Hill—Mirpur-Undwaria area. **Marwar State**— General character—Composition; More basic lavas; Tuffs; Breccias; Conglomerates; Mode of effusion. **North-western Jaipur. South-eastern Bikaner and the Marwar-Bikaner frontier**:—Jhunjhunu—Biramsar—Randisar—Lodsar and Taonra—**Hissar district, Punjab. Jech Doab and Rechna Doab, Western Punjab**—Position and Peninsular character—Kirana Hills— Chiniot Hills—Sangla Hills—Shahkot Hills—Comparison with the Malani area. II. **Sedimentaries. Formation of the Aravalli range.**

Land barrier between the north and the south.—The land barrier which is believed to have separated a northern from a southern sea during the Cuddapah period, persisted into that of the Vindhyan, whose rocks, by the variation of their facies and if rightly equated, make the presence of this great tongue of land somewhat more recognisable. This barrier divides the great northern Vindhyan basin from one to the south embracing the Kurnool, Bhima, Sullavai and other formations, all of which, from their position in the geological sequence and their lithological character, are, with much uncertainty, referred to the Lower Vindhyan. This ancient divide is, as we have seen, a ridge of gneiss which to the west forms the well-raised base of the basaltic plateau of Deccan Trap throughout the districts of Mandla, Seoni, Chhindwara and Betul, and to the northeast gives rise to the highlands of Chota Nagpur. Interrupted by Gondwana deposits stretching across from the Son to the Mahanadi, the gneissic ridge extends in a direction generally E.N.E.–W.S.W. or N.E.–S.W. At first sight its approximate parallelism to the distant Aravalli chain might be taken as a suggestive indication of the physiographical and tectonic trend during the Cuddapah and Vindhyan periods ; the Aravalli strike, however, splays out to the south, and there is good reason to believe that one branch swings round towards the east and becomes continuous with the strike of the old rocks along the flank of the gneissic ridge. The marginal disturbance noticed along one of the boundaries in many of the Purana basins is to be seen along that edge of the main Vindhyan basin which occupies the Son valley, and locally along the boundary of the Bhima basin. Commencing with the southern side of the ridge, the best known of the areas now to be considered is that of Kurnool and, although farther from the land barrier than the others, it will be described first as the type area of what is regarded uncertainly as the southern Vindhyan sea.

KURNOOL SERIES, MADRAS.

General Position.—In the type area of Madras, the outcrop of the Kurnool series, except in the neighbourhood of the town after which it has been named lies entirely within the open basin of the Cuddapah system. Here the beds are found in two separate areas, the larger of which occupies the whole of the Kunderu (Kundair) valley and stretches beyond the Kistna, while the smaller lies to the northeast in the district known as the Palnad. The series lies unconformably upon the Cuddapahs and reaches a total thickness of only 1,200 feet, which is less than that of the smallest series of the Cuddapahs. Along the east side of its outcrop, it has felt the full effects of the disturbance which the underlying Cuddapahs have suffered and which seems to have persisted spasmodically throughout the Cuddapah, Kurnool and following epochs, and may possibly have been rejuvenated in much later times. That the movement which produced such disturbance was not all post-Kurnool in age is definitely illustrated by an old fault, in the Cuddapah rocks which Coulson[1] has shown, has not affected the overlying Kurnools.

Relationships and subdivision.—There is a lithological resemblance between the Kurnools and the Lower Vindhyan of the Son valley and indeed, if the volcanic rocks of the latter be omitted, the sequence in the two cases is generally comparable—a sandstone and conglomerate stage at the base, followed by two principal limestone horizons separated from each other by shales and sandstones.[1] The Kurnool series is mainly a limestone formation with subordinate bands of sandstone and shale, and was divided by W. King into the following stages[2] at Nandial :—

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[1] *Rec.*, LXVI, 438 (1932).

Kundair (Khoond-air) stage	Nandyal (Nandial) shales.
	Koilkuntla (Koilkoontla) limestone
Paniam (Paneum) stage	Pinnacled quartzites.
	Plateau quartzites.
Jamalamadugu (Jummulmudgoo) stage	Auk (Owk) shales.
	Narji (Nerjee) limestones.
Banganapalli (Banaganpilly) stage	(Sandstones).

Banganapalli stage.—The Banganapalli stage consists of dark red, grey or brown sandstones, generally coarse, often earthy, and occasionally felspathic or ferruginous. Pebble beds are frequent, the pebbles being small and numerous, and composed of quartzite and variously coloured cherts, jaspers and hardened shales derived from the cherty shales of the Cheyair series of the Cuddapah, on which the Banganapalli stage generally and unconformably rests. The basal bed, often a quartzite, can be seen lying unconformably upon at least three of the different series into which the Cuddapahs have been divided. The beds of the Banganapalli stage differ in no important respects from beds of the same kind in the underlying Cuddapahs, such as the Gulcherus and Pulivendlas, but are distinguishable therefrom by their position. Their thickness may rise to 70 or 100 feet, but is seldom more than 20 feet ; often it is reduced to 4 or 5 feet.

Diamond fields.—The Banganapalli beds are of interest as being the principa source of the diamond in the Cuddapah basin, and are in this respect comparable to the Tirohan breccia of the Lower Vindhyan deposits of Bundelkhand, in another Indian diamond field, namely that of Panna. The gems, however, are thought to have been derived and re-sorted from the trap sills intrusive into the Vaimpalli and Cheyair series of the underlying Cuddapah system. One reason for this suggestion is the similarity of the rock of these Cuddapah sills to the decomposed basic rock found at the neighbouring diamond-bearing locality of Wajra Karur in the Anantapur district (see p. 365).[3] A similar primary derivation has been deduced in the case of the Bundelkhand gems.

In many places on or near rocks of the Kurnool series, diamonds have been collected in surface gravels, and stones are from time to time turned up by the plough. One of the latest finds, a diamond one inch long, half-an-inch wide and a quarter-of-an-inch thick, was picked up in 1935 about fifteen miles northeast of Wajra Karur by a cultivator.[4] At Banganapalli, workings are carried on in the solid rocks. Shallow pits, not more than fifteen feet deep, are sunk in the rock, which is hard and quartzitic at the surface, but soft and easily worked underground. Short galleries are driven in the diamond layer at or close to the base of the stage, where the gems occur in some of the more clayey and pebbly horizons. A noteworthy feature is the perfection of many of the crystals; but the detrital nature of their immediate origin is deduced from the character of the rock in which they are found. In their detrital derivation they resemble the gems of the Witwatersrand area in South Africa. A concentration of the diamonds within certain areas has been reported in the case of southern India. Besides those in the neighbourhood of Banganapalli, several other rock-workings in the Kurnool district have yielded stones of value in the past.

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[1] Auden suggests that the Kurnools should be equated with the upper half of the Upper Vindhyan (*Mem.* LXII, 247 (1933)).

[2] *Mem.*, VIII, 39-40 (1872).

[3] *Gen. Rep., Rec.*, LXVII, 28-29 (1933).

[4] *Gen. Rep.,Rec.*, LXXI, 39 (1936).

Golconda, although a name with which the Indian diamond industry has been historically associated, never possessed any diamond mines but was merely a mart at which stones were sold or bartered. Mention of a trade in Indian diamonds dates back to the time of Ptolemy, and even further still in the Hindu classics, and export of the stones is said to have begun about 500 B.C. The earliest detailed description of the mines came from the pen of the Portuguese physician Garcia de Orta in 1565. As a dealer in precious stones Jean Baptiste Tavernier visited the Indian diamond fields in the middle of the seventeenth century, at which time the buying and selling of diamonds was conducted by young children. India practically held a monopoly in this industry until the discovery of these gems in South Africa and Brazil; the production in India is now insignificant.

There is little doubt that all the famous diamonds of antiquity must have come from India. The Kollur mines of the Guntur district in the year 1645 employed close upon 60,000 persons. It was from these mines that the Great Moghul diamond is said to have been derived; in the rough it is reported to have weighed 900 *ratis* (787½ carats), but is said to have been reduced in the process of cutting to 280 carats. The "Great Moghul" was shown to Tavernier in 1665. It has been suggested that the Koh-i-nur, brought to England and presented to Queen Victoria in 1850 by the East India Company, was a portion of the mutilated Moghul stone, but it seems more likely that the Great Moghul is the diamond now in the treasury of Teheran. According to one story, the "Great Moghul" was given to Prince Humayon by the Rajah and people of Gwalior as a thanks-offering for having saved their lives and property from his soldiery during Baber's invasion of Hindustan. Another account affirms that it was presented to the Emperor Shah Jehan in 1656, but this stone is more likely to have been the "Shah", a diamond with a yellowish water. A. Fersman identifies the "Great Moghul" with the "Orlov" diamond in the sceptre of the Russian Czars; whatever its origin, the latter gem of just under 195 carats of a beautiful pale bluish green tint, and one of the finest diamonds ever seen, is reported to have been stolen from a temple in Mysore, and to have been buried in a man's leg for six months. The ancient cutting of this stone remains intact. The crystal which gave birth to the Orlov is estimated to have been a rounded dodecahedron weighing about 350 carats. The Koh-i-nur is the principal jewel in the crown which was used for the coronation of Queen Alexandra. The ill-omened "Hope" diamond, perhaps a portion of a 112-carat stone found at Kollur and brought to Europe by Tavernier, had a steely greenish blue lustre; the other part of the parent stone, a 67-carat diamond, was stolen from the French crown jewels during the Revolution. The "Pitt" or "Regent diamond, which figured in the State sword worn by Napoleon and is now in the Louvre, is said to have come from the Kistna district; its original weight of 410 carats was reduced by cutting to nearly 137 carats. The "Pitt" and the "Sancy" diamonds were also stolen during the French Revolution, but both were subsequently recovered. The "Sancy", a smaller stone, came into the possession successively of Charles the Bold, De Sancy, Queen Elizabeth of England, Queen Henrietta Maria, Cardinal Mazarin and Louis XIV. The "Shah" diamond ("Moon of the Mountains") one of the jewels in the Russian crown, came from India and bears three Persian inscriptions, the oldest of which refers to Burhan-Nizam-Shah II who was Regent of the province of Ahmadnagar and is dated 1000 (1591 A. D.); the second inscription names Shah Jehan, Son of Jehangir and is dated 1051 (1641 A. D.); while the third records Kajar-Fath'ali-Shah Sultan, 1242 (1824 A. D.), Shah of Persia. It seems highly probable that the "Shah" diamond formed part of the treasure which fell into the hands of Akbar at the conquest of Ahmadnagar, now a district in Bombay, in 1595. It is said to have been part of Nadir Shah's loot from Delhi in 1738. (*Bull. Acad. Sci. Russ.*, 1922, p. 451, note and 1926, p. 1.) Its final passage from Persia to Russia was carried out to placate the Czar for the murder of a Russian diplomatic agent in Teheran in 1829.

Several smaller diamonds in the Russian regalia must have come originally from India, judging from their Hindu mode of cutting.

Jamalamadugu stage.—The Jamalamadugu stage takes its name from a large village on the west side of the Kunderu valley. The Narji limestone of this stage rises in terraces, to which the Banganapalli beds form an outer fringe. It is finely crystalline or compact, generally blue-grey, sometimes nearly black, and occasionally of a pale buff colour. The non-compact, crystalline variety is somewhat siliceous in composition. The blue variety, which is crystalline and compact, weathers with surfaces resembling certain corals. An inferior lithographic stone used to be obtained from these beds, but the rock is now employed chiefly for building purposes; it is quarried near the railway at Narji village, by which name the stone is commercially known. West of Banganapalli, this limestone subdivision is about 400 feet thick, but thins out to the north and south. Around Kurnool it rests on the gneiss, where it becomes cherty and brecciated in a peculiar manner. It is regarded as a shore deposit, lying upon the grits of the Banganapalli stage or overlapping them and lying directly upon the gneiss or granite.

The Narji limestone passes up gradually into buff, white and purplish shales well seen near the village of Auk. The maximum thickness of the sub-stage is 50 feet. Occasionally thin discoidal bodies of a dark-brown colour, about $\frac{1}{16}$th or $\frac{1}{8}$ th of an inch in diameter, are observable on the surfaces of the shale laminae, but have so far resisted attempts at identification.

Paniam stage.—Between the open Kunderu valley and the western ranges, there are in the Kurnool district some low flat hills, such as the plateaux of Uppalapadu (Upalpad) and Undutla. These low plateaux are composed of a sandstone or quartzite locally intercalated amongst the members of the Kurnool series and known as the Paniam stage after the town of that name. The greatest thickness of the stage is only 100 feet and it disappears altogether to the north and south, nor has any sign of it been observed on the eastern edge of the basin

An upper subdivision of this stage, formed of firm white sandstone, has been distinguished under the name of the "Pinnacled quartzites" from its mode of weathering. The lower beds of "Plateau quartzites" are coarser, more earthy and ferruginous, occasionally conglomeratic with pebbles and clay-balls; they rest conformably upon the Auk shales.

Kundair stage.—In a basin of slightly disturbed strata, the uppermost group naturally covers the largest area, and so the Kundair beds occupy the whole valley of the Kundair or Kunderu. There is a thickness of from 500 to 600 feet. The upper two-thirds, consisting of purple calcareous shales and earthy limestones, and distinguished as the Nandyal shales, pass insensibly down into purer, compact, cryptocrystalline, flaggy limestones, known as the Koilkuntla band, in which are found numerous discoidal markings of from half-an-inch to two inches in diameter, and small papillae resembling casts of *Cypris*. The town of Cuddapah and all the large villages in the centre of the valley lie upon the Nandyal shales. Here the rock is soft and crumbling, but to the south and east, on the margin of the mountain region, these uppermost beds of the basin are quite slaty, being cleaved and contorted proportionally with the underlying formations. As in some of the Cuddapah subdivisions, the lithological character of the Kundair stage changes to the northwest, and in the proximity of the gneiss the Koilkuntla beds are described as shore deposits, which, it is thought, never extended much beyond their present boundary.

The Palnad.—In the flat basin of the Palnad, there is a large exposure of limestones which are believed to be of Kurnool age. In the southwest corner the various stages of the series can be recognised, in most cases with ease. Red or purple calcareous shales overlying earthy blue limestones represent respectively the Nandyal shales and the Koilkuntla limestone. These beds overlie quartzites which answer very well to the Plateau quartzites of the Paniam stage. Beneath the latter are obvious representatives of the Auk shales and the Narji limestones. Beneath these again come traces of quartzites, sandstones and conglomerates, answering to the Banganapalli stage; these beds in places have been worked for diamonds. The Pinnacled beds have not been recognised and the lowest quartzites are easily confused with the quartzites of Cuddapah age (Kistna series) on which they rest. Diamonds appear to be restricted to quartzites immediately underlying the limestone, from which it seems reasonable to infer that the quartzites belong to the Banganapalli stage.

The leading structural character of the Cuddapah basin is maintained in the Palnad. On the west side the strata are comparatively undisturbed, while on the eastern border they are cleaved, foliated and contorted, and appear to be overlain by a natural ascending sequence of shales, limestones and quartzites which may be either an inverted repetition of the Kurnool stages enumerated above, or newer stages of the Kurnool series.

A third outlier.—A third but very small outlier of the Kurnools—the Veludurti outlier is to be seen within the same Cuddapah outcrop, about ten miles southwest of the edge of the Palnad exposure at the great bend of the Kistna.[1] These beds include the Narji limestone lying nearly horizontally and apparently quite conformably upon the quartzites of the plateau through which the river flows in that region.

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[1] King. *Mem.*, VIII, 109 (1872).

BHIMA SERIES OF HYDERABAD AND SOUTHERN BOMBAY.

Position and relationships.—On the northwestern border of the Cuddapah basin, the Kurnool deposits overlap the stages of the Cuddapah formation upon which for the most part they rest, and lie upon the gneiss for a short distance up the Kistna valley. Seventy-five miles further in this northwesterly direction there is another area of rocks having a strong likeness to the Kurnool deposits, lying within the Gulbarga district of Hyderabad and continuing at its south-western end for a few miles into the Bijapur district of the Bombay Presidency. These deposits rest throughout their entire southeastern border, for more than a hundred miles immediately upon the gneiss, while along their entire north-western border they are covered by the Deccan Trap. The outcrop of this series commences some eight miles to the eastward of the extreme northeastern corner of the Kaladgi basin, but the rocks differ considerably from the Kaladgi rocks.[1] The width of the basin thus exposed is exceedingly variable, both boundaries being very irregular in outline; its maximum, about twenty-five miles, occurs where the river Bhima crosses the outcrop nearly at its middle. This Bhima series is nowhere in contact with the Kaladgis, but its similarity to the Kurnools leads us to conclude that it bears much the same relationship to the Kaladgis as the Kurnools do to the Cuddapah beds.

Subdivision.—The Bhima series is mainly a limestone formation which, in the central portion of the basin, has been subdivided as follows:—

	(in feet.)
Upper—	
(*g*) Red calcareous shale	30
(*f*) Flaggy limestone beds	?
(*e*) Buff shales	18
(*d*) Quartzite (sandstone)	200
(*c*) Limestones—	
(iii) Blue, thick-bedded, splintery limestone, brecciated in part	200
(ii) Thin-bedded limestone with chert	20
(i) Blue and grey, splintery limestone, occasionally brecciated	200
Lower—	
(*b*) Purple, red, drab and dark green shales, with calcareous flags at the top	100
(*a*) Sandstones or quartzites, and conglomerates	90

Lower division.—It is principally in the southwestern part of the area that the bottom arenaceous beds are developed to any extent. The pebbles of the conglomeratic bands were evidently derived from the degradation of the adjacent gneiss, upon a very uneven surface of which the Bhima deposits were laid down; this floor rock furnished the quartz and red felspar which make up the bulk of the pebbles, many of which in the case of the latter mineral occur in broken angular pieces so little rounded as to give the bed more the appearance of a breccia. In the eastern border of the basin, the basement bed at one spot is a brown pebbly conglomerate with rolled pebbles of quartz and gneiss, and among them a rolled fragment of material resembling silicified wood or bone was found. These basal beds were deposited in shallow water on an uneven floor of the gneiss, in some cases around the base of low gneissic islands in the Bhima sea ; this is shown by the very winding outline of the boundary between the two kinds of rock, and by the occurrence of gneissic inliers which, in places, can be seen protruding far above the base of the sedimentary series, rising in large hummocks upwards of a hundred feet high from among the shaly sandstones, and actually towering over the level of the limestone plateau close by. Some of these inliers are found near the margin of the Trap, and there is thus no presumptive evidence that the sedimentary Bhima basin extends far beneath the lava. The actual basement bed is sometimes a gritty sandstone instead of a conglomerate, but the latter type is on the whole predominant. The sandstones are sometimes rippled, and occasionally approximate quartzites in texture. One of the flaggy varieties has been used in the construction of the fine group of ancient dolmens standing half-a-mile west of Bazuna Kolur (Rajan Kollur), and some of the grits have been employed in the manufacture of prehistoric millstones.

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[1] R. Bruce Foote. *Mem.*, XII, 139 (1876). Man., 2nd Edit., 87 (1893).

Diamond beds.—At Bachimali, the extreme eastern point of the southern expansion of the Bhima basin, there is a basement pebble bed much resembling the diamond layers of the lower Kistna valley. It is much broken up by small pits, as if at one time it had been searched for diamonds, but the only reference to such an occurrence seems to be one by the old French traveller, Tavernier, who mentions the existence of diamond mines near Bijapur, a town over fifty miles away.

Shale state.—The purple and green shale stage is well seen at the eastern end of the Tirth plateau, as well as to the southeast of Talikot and along the road from that village to Sorapur.

Overlap of the Upper over the Lower division.—Although the purple and red shales appear to graduate upwards into the limestones of the Upper subdivision of the series, a well-marked and extensive overlap of these limestones on to the gneissic rocks along the southern boundary of the basin, east of Kembhawi, indicates either a break in time between the deposition of the calcareous shales forming the top of the Lower subdivision and the limestone stages of the Upper, or a rapid deepening and extension northeastwards of the sea in which the Bhima rocks were laid down.

Upper division.—The lowest and by far the most important stage of the Upper Bhima group includes the Talikot limestones, largely exposed at and around the town of Talikot in the western part of the Bhima area, and still more extensively along the Bhima valley and its tributary, the Kogni. The rock is, for the most part, fine in grain, and has a texture approaching that of lithographic stone. Grey is the prevailing colour, but drab and pink tints are common, and other colours occur. The rock is found generally in flaggy beds and is used almost exclusively as the local building material. Only about 80 feet of this stage are present near Talikot, but farther to the northeast additional higher horizons come in and greatly increase this estimate. The quartzite or sandstone of the Upper Bhimas is quite a local intercalation, so that in some sections the succession is almost exclusively made up of limestones. The limestone breccia of Yeddihalli is so much at variance with the pelagic character of the limestone which in the immediate neighbourhood forms the basement of the Bhima series, that the patches in which it occurs are thought to be remnants of a former spread of the Kaladgi rocks, in which such breccias are frequent. The Bhima limestones have been noticed in places to have assumed a white colour and a more crystalline texture when in contact with the overlying Deccan Trap.

Along the northwest border, where the Bhima river emerges from the Trap area, the red and purple shales, which form the highest known member of the Bhima series, are seen extending under the Trap. It is quite possible, therefore, that yet higher and younger members of the series lie concealed northwestwards beneath the Trap.

Disturbance.—The Bhima formation has undergone very little disturbance and the inclination of the strata rarely exceeds 5°. At a few places near the boundary, some crushing and faulting have taken place, as for example at Gogi, where the lowest beds are vertical.

Relationship to the Kurnool.—In view of the open-sea conditions indicated by the limestones of the Upper Bhimas, there is a suggestion that they were once continuous with the like rocks of the Kurnool area which are only some seventy or eighty miles distant to the southeast, and that they have been separated therefrom by denudation.[1] Such a suggestion is borne out by the noticeable similarity in general sequence between the Kurnools and Bhimas. The Bhima series is undoubtedly the equivalent, more or less, of the Kurnool; its uncertain correlation with the Lower Vindhyan rests upon its stratigraphical position.

GODAVARI AND MAHANADI AREAS.

Uncertain stratigraphical position.—Between the Kurnool and Bhima basins on the south, and the main Vindhyan basin on the north, there are numerous areas, some of them extensive, in the Godavari and Mahanadi river basins, occupied by rocks belonging either to the Lower Vindhyan or to the Cuddapah or to both. Like the Kurnool and Bhima basins, they lie to the south of the gneissic land barrier mentioned at the beginning of this chapter. There is much doubt regarding the precise geological position of these successions which, in a general way, comprise an older arenaceous set of beds overlain by younger limestones and shales. Most of them have been described under the heading of Purana; two of them are included in the present chapter, but all these ancient but post-Archaean occurrences need a re-survey. The Penganga beds of the Godavari basin (*vide* p. 371) were at one time classed as equivalent to the Kurnool or Lower Vindhyan. The Upper group of the Chhattisgarh basin, consisting of limestones and purple shales (*vide* p. 375), was similarly dated by F. H. Smith[2] but, for no very strong reason, has also been included in this work under the heading of Purana. Ball referred the whole of the Chhattisgarh basin rocks to the Vindhyan. The presence of Lower Vindhyan rocks somewhere in the Barapahar hills, which constitute the eastern prolongation of the Chhattisgarh outcrop, is to some extent rendered probable by the occurrence of diamonds in the bed of the Mahanadi as far up as Chandarpur. Rocks in the Barapahar hills were said by Ball to show a general lithological resemblance to the diamond-bearing Vindhyans of Panna State, Bundelkhand, as well as to the diamantiferous Banganapalli beds of Madras. The tradition of the presence of diamonds in the Mahanadi locality is an ancient one, and stones of 99 and 45 carats are reported. There is no record of diamonds from the Noagarh-Khariar plateau (*vide* p. 374). As already recorded, both the lower and upper groups of the Chhattisgarh rocks are traversed by dykes of basic trap which may be of Vindhyan age. The upper group of the Chhattisgarhs is itself not without lithological and positional resemblances to the Kurnools.

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[1] Dr. King, on the other hand, was of the opinion that the Kurnools belonged to a separate basin, round the whole boundary of which he speaks of "evidences of long shelving shores", (*Mem.*, VIII, 122 (1872).)

[2] *Gen. Rep.* 1897-98, 44; *Ibid.*, 1898-99, 41.

SULLAVAI SERIES.

Some moderate-sized outliers, consisting mostly of sandstone and quartzite on or near the banks of the Godavari and Pranhita in the Adilabad district of the Nizam's dominions and the Chanda district of the Central Provinces, were designated the "Sullavai series" by King, and referred to the Lower Vindhyan.[1] There has always been considerable doubt as to this correlation, and actually these beds have more lithological resemblance to the Cuddapahs. The Sullavai beds are said to lie unconformably upon the Pakhal series and sections are recorded in which the former beds are said to rest almost horizontally upon the eroded edges of the nearly vertical Pakhal shales and quartzites. Over most of the area, however, indications of unconformity are apparently limited more or less to overlap, and near Sullavai village there is a remarkable parallelism of dip and strike between the two formations. The thickness of the Pakhals is little more than one-third of that of the Madras Cuddapahs, some of whose component series are separated from each other by denudation-unconformity as well as overlap, so that the only serious objection to the Sullavais being a continuation of the Pakhal sequence and representing higher horizons of the Cuddapah, seems to be the local severity of the unconformity. Recently, Dr. Heron has expressed the view that the Pakhal and Sullavai may be but different facies of the same geological formation (private communication).

The Sullavai series consists typically of a massive quartzitic sandstone and conglomerate with a few slaty beds, overlain by sandstones generally of a salmon or chocolate colour, capped by a conspicuous series of thin-bedded and thicker bedded pebbly quartzites or indurated sandstones which weather in the peculiar and picturesque manner characteristic of the Pinnacled quartzites of the Kurnool series in its type area. In other respects there are considerable differences between the Sullavais and the Kurnools. There are, for instance, no limestones in the former while the latter is essentially a limestone formation; the sequence of deposits in the two areas is also dissimilar. The Sullavai beds have been recognised in the hills near Dewalmari on the Pranhita (Wardha) river, where a sandstone has been compared with that of the Chimur-Mul exposures, regarded as of Vindhyan age, east of the Wardha valley coalfield.

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[1] *Mem.*, XVIII, pt. 3, 77 (1930-reprint).

The thickness of the Sullavai series where best developed in the Dewalmari hills and in the western outcrop near Kapra is stated to be as follows[1] :

	Kapra. (in feet)	Dewalmari hills. (in feet)
3. Kapra quartzites and conglomerates	100	700
2. Venkatpur salmon and chocolate sandstones . .	200	300
1. Encharani quartzites	900	600
	1,200	1,600

CHIMUR-MUL AREA.

Some sandstones in the region between Chimur (Chimmur) and Mul (Muhl) in the Chanda district of the Central Provinces, east of the Wardha (Pranhita) valley coalfield, were regarded by W. T. Blanford as identical with the Sullavai beds of Dewalmari.[2] These sandstones are white and purplish in colour, quartzitic in texture, and break with a distinct conchoidal fracture. They are described as being associated with a coarse more or less felspathic grit, which decomposes into a very soft rock easily mistaken for Damuda sandstone. Two small outcrops of these rocks are to be seen southwest of the main exposure, one about sixteen miles west of Chanda and the other commencing twenty miles south of the same town. In the former, several bands of conglomerate occur, containing pebbles of haematite, from which the iron formerly made at Yenak was obtained ; one of these bands is in places nine feet broad. In the latter area, which is within the Nizam's Dominions and was mapped by King as Pakhal, the upper beds are also conglomeratic and all are more or less stained with iron.[3] Other still smaller inliers are recorded in the neighbourhood of Warora. As already noted, the lower Godavari and Pranhita valleys require geological re-investigation.

THE VINDHYAN SYSTEM OF THE NORTHERN PART OF THE PENINSULA.

Subdivision.—The term Vindhyan, one of the oldest introduced by the Geological Survey of India, was adopted from the name applied by geographers to the scarped "range" along the north side of the Narbada valley, and was employed by Dr. T. Oldham in 1856 to designate the great sandstone formation of Bundelkhand and Malwa. Throughout a large proportion of its border, this great sandstone formation is unconformably related to the ancient Archaean gneisses or the Dharwars (Bijawars or Gwaliors) but, along the eastward extension of its outcrop in Bundelkhand and the Son valley, as well as in the neighbourhood of Chitor and Jhalra Patan at the western corner of the basin, it rests with no visible discordance, except in the case of one or two outliers, upon deposits of a much younger character. The latter, called alternatively the Semri series (Medlicott, 1860 ; named after the Semri or Siamri river in Bijawar) or the Son series (Vredenburg, 1906), were soon realised to be nearly related to the great formation they underlay and, for this reason, were included as a Lower division of the Vindhyan system, the overlying succession, comprising the Kaimur, Rewah and Bhander series, thus becoming the " Upper Vindhyan ".

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[1] King. *Mem.*, XVIII, pt. 3, pp. 79, 81 (1930-reprint.)

[2] *Ibid.* pt. 3, 83 (1930-reprint).

[3] *Mem.*, XIII, 12, 13 (1877).

Opinions differ as to the suitability of this scheme, the main objection being the disproportionate sizes of the two divisions, for the maximum thickness of the Upper is between three and four times that of the exposed Lower.[1] Revised schemes of classification have been put forward,[2] the simplest and most recent of which is one by Auden, who divides the system into four more or less equipartite series—the Semri, the Kaimur, the Rewah and the Bhander, in ascending order—and suggests the disuse of the terms " Lower Vindhyan " and " Upper Vindhyan ". While accepting the above simple grouping, however, it is not proposed to discard the terms Lower Vindhyan and Upper Vindhyan[3] for the following reasons : (i) the terms have been in use for a long time ; (ii) although local unconformities have been noted at several horizons in the system, the discordance between the Upper and Lower Vindhyan, in the few places where it does occur, is somewhat more conspicuous ; (iii) although there was probably more than one alternation between marine and lacustrine or fluviatile conditions during Vindhyan times, the change from beds of a predominantly marine character to fluviatile deposits is definitely more marked and has more permanency at the dividing surface between the Lower Vindhyan, a strongly calcareous assemblage, and the Upper Vindhyan which is mainly arenaceous[4] ; (iv) the Lower group is described as everywhere distinguishable from the Upper, the stages in the former being indefinite, inconstant, and characterised by flagginess, those in the Upper being thick-bedded, massive and unusually constant ; (v) in places abundant fragments of Lower Vindhyan strata are observable in the lower stages of the Upper division[5] ; (vi) certain exposures, in other parts of the Peninsula, of rocks provisionally referred to the Vindhyan, have more in common with the Lower than with the Upper division of that system, both in facies, geological position and mineral content. Whatever scheme is accepted, there is much in favour of the essential unity of the system as a whole.

Position and extent.—The shape of the great Vindhyan basin is that of an axe with its cutting edge coinciding with the boundary of the Archaean exposure of Rajputana and its haft curving eastwards along the Narbada and Son valleys. In the angle between the " haft " and the " blade " lies the broad tract of the Bundelkhand Granite with its narrow fringe of Bijawars on the south and their equivalents, the Gwaliors, on the north ; another smaller outcrop of the granite curves round the blunt westerly tip of the " axe ". The greater part of the " blade " is concealed beneath the Deccan Trap of the Malwa plateau. To the north, the Vindhyans, as well as the Bundelkhand Granite, Aravallis and Delhis, disappear beneath the alluvium of the Ganges and Jumna, and the limits of Vindhyan deposition in this direction are not known. From Sasaram in the east at the proximal end of the " haft ", to Barwai in the west at the head or southern corner of the " blade ", the distance is 530 miles but a small exposure of Vindhyan rocks at Jobat, about 90 miles west of Barwai, may mean that the basin extends as far as this spot beneath the Trap which cuts off the main exposure at Barwai. The length of the " cutting edge ", from Chitor to Fatehpur Sikri is about 240 miles, and the width of the " blade ", from the Archaean boundary of Rajputana to the Narbada valley, varies from 215 to 285 miles. The average width of the " haft " is about 50 miles and its length some 340 miles. The total area of the basin, including that part of it beneath the Deccan Trap of Malwa but excluding what lies below the Ganges-Jumna alluvium and any extension to Jobat, is little short of 70,000 square miles. There is no evidence of any of the Lower Vindhyan sediments having completely covered the Bundelkhand Granite tract, but some of the younger Vindhyan may have done so; Upper Vindhyan beds extend northwards on either side of the granite underneath the alluvium. The Vindhyan system, even with the exclusion of its supposed equivalents in southern India, ranks third in superficial extent within the rock area of the Peninsula, and is inferior in this respect only to the Gneiss and the Deccan Trap. In most parts of the Peninsula, the disposition of the Vindhyan deposits, as well as of the preceding Cuddapah and, in places, of the later Gondwana sediments, has a definite relationship to the structure of " grain " of the Archaean complex without being always exactly coincident therewith.

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[1] Unless we include the Jungel Shales (*vide* p. 380) with the Lower group, when the proportion would be nearer 2½ times.

[2] E. Vredenburg, for example, suggested that the Lower Vindhyan (Son series), Rewah and Kaimur series should be united under the term " Ken " ; according to this scheme, the Vindhyan system would be divided into the Ken subdivision below and the Bhander subdivision above. *Rec.*, XXXIII, 258-259 (1906).

[3] The two divisions have been differentiated (by a line) on the 32-inch geological map.

[4] P. N. Datta, however, records sections showing a passage from the Lower into the Upper Vindhyan. *Rec.*, XXIX, 77-79 (1896).

[5] F. R. Mallet. *Mem.*, VII, 47 (1869).

Conditions of deposition.—Vredenburg has summarised the conditions under which the Vindhyan sediments, totalling some 14,000 feet or more, are thought to have been laid down.[1] "The formation of the synclinal trough in which the Vindhyans were deposited proceeded *pari passu* with their sedimentation, so that, along the edges of the syncline some of the older divisions became upheaved and exposed to denudation while sedimentation continued uninterrupted nearer the axis of the syncline ". This explanation reconciles the indications of an apparently conformable sequence with the evidence furnished by the frequent occurrence in the Vindhyan conglomerates of fragments derived from a lower horizon of the same system. The conception put forward by Auden with regard to the main Vindhyan basin is that of alternating marine and fluviatile conditions, the latter predominating. Mallet's suggestion of estuarine deposition is considered inapplicable to the bulk of the Vindhyan beds, since such widespread development of sun-cracks, ripple marking, rain-pitting and red colouring as is found at so many horizons in the sequence implies " exposure of whole areas to sub-aerial conditions rather than the limited exposure which would result from the difference between high and low tides along estuarine flats ". For " estuarine " Auden would substitute the word " deltaic ", as regards the Son valley area, because the sediments as now seen suggest " the dominance of fluviatile deposition filling up valleys, instead of the entry of the sea into incised and depressed valleys where fluviatile sedimentation would not be active ".[2] The prevailing type of shale throughout the Vindhyan system is a sharply-bedded, flaggy, siliceous or sandy, sometimes micaceous shale of greenish or rusty tint; a purely argillaceous shale is rare, and in many cases the term mudstone is more applicable.

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[1] *Rec.*, XXXIII, 258 (1906).
[2] *Mem.*, LXII, 221 (1933).

Over large areas there is no visible discordance between the Lower and Upper Vindhyan, and folding and erosion between the two periods seem to have been of a local character ; local unconformities are also occasionally seen at other horizons in the system. Nevertheless, the somewhat abrupt change from the limestone of the uppermost stage of the Lower division, to the sandstone at the base of the Upper, with its wind-rounded grains and tourmaline-content, marks the upheaval of a generally marine series and the commencement of generally a fluviatile one, for, although there was subsequent recurrence of marine incursion, as, for instance, towards the end of the period, it seems to have been more ephemeral.

Age of the system.—Doubtful impressions of organisms, some showing what might be indications of a skeleton or test, have been recorded from time to time and some from the Suket Shales—which appear to be the uppermost stage of the Lower Vindhyan in the Rajputana State of Kotah—have received actual names. These remains, which are assumed to have been chitinous but are now carbonised, were collected by Mr. Cecil Jones beneath the Kaimur quartzite scarp at Rampura in northern Indore. Some authorities agree that the specimens are true fossils, but opinions differ as to their affinities. It was at first suggested by their discoverer that they might represent the genus *Obolella* or the species *Chuaria circularis*, described by C. D. Walcott from " Precambrian " rocks in Arizona, or possibly the operculum of *Hyolithellus*.[1] Some experts have pronounced them to be definitely the remains of primitive brachiopods, agreeing most closely with forms of *Acrothele*, a genus known to occur in the Cambrain of the Salt Range.[2] Another suggestion, founded on the fact that the " test " in some cases, when heated, glows and burns to a grey ash, is that the specimens are of vegetable origin. One of the latest authorities consulted, Dr. F. Chapman of Melbourne, has felt justified in determining specimens submitted to him as comprising a species of the new genus *Protobolella*—*Protobolella jonesi*—and three species of a second new genus—*Fermoria minima* (replacing a form at first called *Neobolus minimus* and comparable with *N. warthi* from the Cambrian of the Salt Range), *F. tripartita* and *F. granulosa*.[3] Dr. M. R. Sahni is of the opinion that there is insufficient evidence for the erection of more than one species of *Fermoria*, namely, *F. minima*, and he places *Protobolella jonesi* in synonymy therewith and has proposed the name *Vindhyanella* for the specimen figured by Chapman in his Pl. 2, Fig. 1 (1935) ; the latter—*Vindhyanella jonesi*—was the specimen which most resembled a brachiopod but it is unfortunately missing.[4] Although the probabilities are that the Suket impressions belong to some archaic form of brachiopod, no reliable feature definitely attributable to this class of organism can be indisputably recognised in the remains. In the debris from the fluorite-bearing Rohtas limestone at Saraidanr near Rohtas—the highest stage of the Lower Vindhyan—a very clear spiral but structureless impression has been observed and figured by Mr. E. J. Beer.[5] Mr. K. Chao has put forward the suggestion that the concentric structures in some of the Vindhyan limestones may perhaps

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[1] *Bull. Geol. Soc. Amer.*, X, 234 (1899).

[2] *Gen. Rep. Rec.*, LXI, 21 (1929).

[3] *Rec.*, LXVII, 20 (1933) ; *Ibid.*, LXIX, 109 (1935).

[4] *Rec.*, LXIX, 467 (1935).

[5] *Rec.*, L, 139 (1919) ; also Plate 30 of the same volume (*Vide* Fig. 2 of the Plate facing p .517 of the Manual).

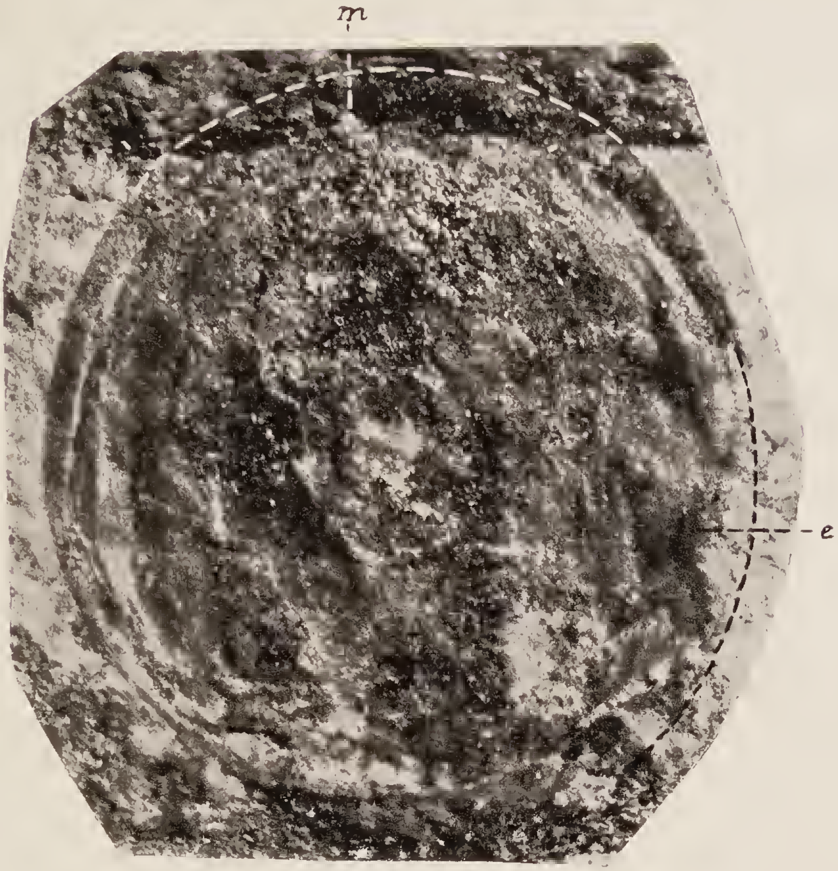

Fig. 1.

(× 18 approx.)

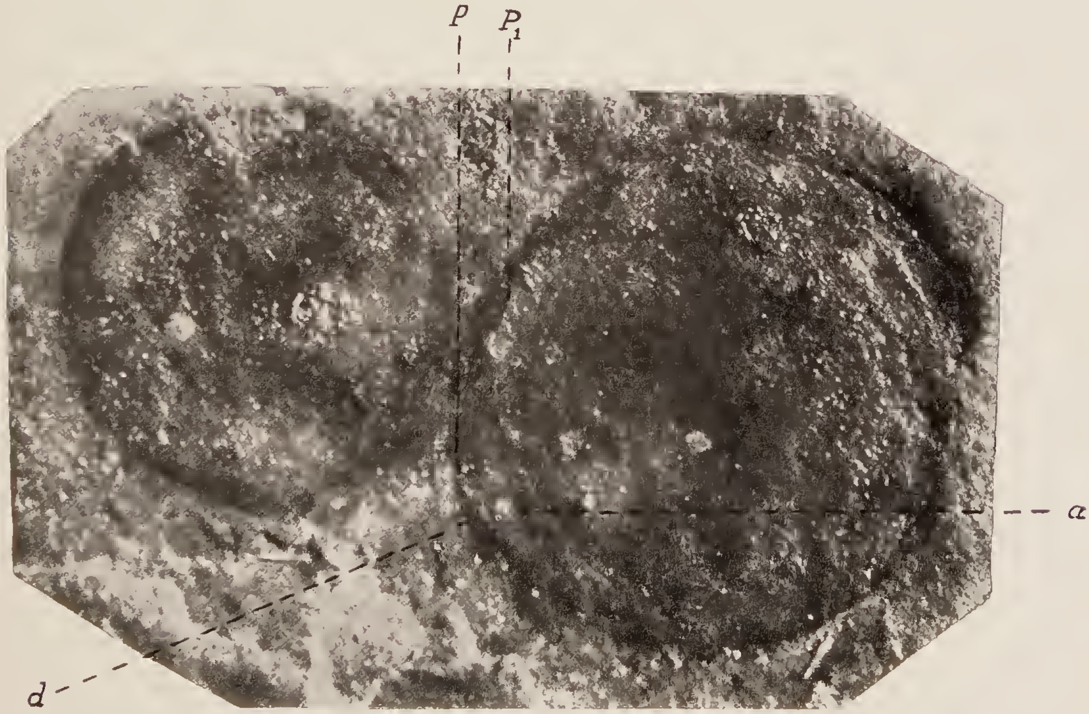

Fig. 2.

(× 21 approx.)

ORGANIC REMAINS FROM THE VINDHYANS.

M. R. Sahni & S. N. Das, photos.

G. S. I., Calcutta.

represent the alga *Collenia*, so common in Sinian rocks of China and North America.[1] The upper half of the Lower Vindhyan is characterised by the presence of glauconite, a mineral usually indicative of organic life.

All that is definitely known concerning the age of the Vindhyan system is that it is older than the Gondwana and younger than the Gwalior (Dharwar), and we have the choice between Purana (probably late Purana) and early Palæozoic. An assumption that the Lower Vindhyan represents the lower half of the Cambrian would make the Upper Vindhyan equivalent perhaps to the Upper Cambrian *plus* an unknown portion of the succeeding system or systems. This would admittedly fill a gap in the geological sequence, for there are no other sediments in the Indian Peninsula which could with probability represent any part of that sequence from the Cambrian to the Lower Carboniferous. That such a long period of time should be entirely unrepresented over such an extensive area is of course possible though the odds seem slightly more in favour of some relics of the Palæozoic rivers, estuaries or seas surviving. Nevertheless, there is no proof that the Vindhyans are Palæozoic, any more than there is that they are older. The Nullagine series of Australia, which has yielded at least eight distinct types of animal remains, all of them differing considerably from known Cambrian forms, is generally regarded as of pre-Cambrian age.

The continent of Gondwanaland, of which the Indian Peninsula formed a part, may have been nearer the South Pole in Vindhyan times than it is today. In whatever latitude it may have lain, there is good reason to conclude that the Vindhyans, and more especially the Upper Vindhyans, accumulated under an arid climate. Similar conditions appear to be indicated in this part of India by the Cambrian sediments of the Salt Range, especially by the Salt Pseudomorph beds and the Saline series, if the latter is rightly referred to the Cambrian ; these Cambrian beds have features closely comparable with those of some of the Vindhyan stages. The Purple Sandstone, also of the Salt Range, which may be older than the Cambrian, is not unlike some of the Vindhyan sandstones.

The Vindhyan has been tentatively correlated with the Keweenawan of Canada and the Jotnian of Fennoscandia, but there is little to choose between this view and the view that it belongs to the earliest part of the Palæozoic.

General lack of disturbance except along specific Zones.—Over almost the whole of the area occupied by the Vindhyan beds, they lie little disturbed and nearly horizontal. In the Kaimur scarp the sandstone dips inwards—*i.e.*, northwards—at an angle which seldom exceeds 20^0 or is less than 5^0 and which averages about 10^0 or 12^0. Northwards the dip dies out and a few miles from the cliff edge the beds are nearly horizontal. The local irregularity in dip of the Kaimur Sandstone between the Panwari ridge and the main plateau south of Tirohan (Tarahwan) is thought to be the result merely of underground solution of the Rohtas Limestone and consequent subsidence. Over the wide expanse of Vindhyan rocks between Gwalior and Nimach, the Bhander and Rewah beds lie comparatively flatly, and it is presumed that to a considerable extent they stretch in this manner southwards under the Deccan Trap of Malwa. North of the Malwa plateau, signs of disturbance are restricted to the Jhalra Patan area and to the Aravalli margin of the basin ; south of the plateau, such signs are observable along the Narbada valley and the Dhar Forest area.

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[1] *Bull. Geol. Soc.* China, XV, 446 (1936).

Localised zones of disturbance.—In the Son valley, folding is more important than faulting and becomes tighter towards the south, a result partly but not entirely of the lesser competency of the Lower Vindhyans which in that direction make their appearance below the more resistant Kaimur beds. Auden finds reason to conclude that some of this folding, as well as some of the pronounced jointing which characterises the Vindhyans of this area, occurred during Vindhyan times.[1] Down the Narbada valley towards Hoshangabad the dips in the Vindhyans along the southern border of their basin become unsteady ; along this line the rocks are faulted, thrown up vertically and even inverted. This disturbance of the strata, to as far west as Hoshangabad, appears at first sight to be a recurrence of the compression which had produced the contortion and cleavage in the adjoining gneisses and other older rocks. It seems to have taken different forms in different parts of the ground. Further east, along the whole Son valley, there is little or no faulting in the zone of disturbance, but at the Son-Narbada watershed one or more faults occur at and close to the boundary, the E.N.E.-W.S.W. strike being remarkably steady throughout.

At Hoshangabad, and again in the Dhar Forest area, there is a decided predominance of a N.W.-S.E. strike, and since the E.N.E.-W.S.W. strike remains constant in the contiguous Bijawars and gneisses, it may be inferred that the N.W.-S.E. strike is the later of the two. It is that to which the features of the Vindhyan rocks at Jhalra Patan on the other (northern) side of the great spread of Deccan Trap conform ; here the Vindhyan strata have been thrown up in a sharp N.W.-S.E. anticlinal flexure, passing southeastwards beneath the Trap, the dips on each side rising to 70°, the sandstones weathering into long narrow ridges. The fold gradually dies out to the northwest. This area is also interesting as affording an instance of the intrusion of Vindhyan rocks by dykes of the Deccan Trap. North of Rampura is a large E.--W. dyke of columnar basalt, some five miles long ; elsewhere small intrusions of dolerite are numerous. The swing-round of the Vindhyan strike is seen to be rapid to the east of Saugor. Traced westwards from Bundelkhand, where it is E.N.E.-W.S.W., it changes to E.-W. then to N.W.--S.E., and through N.--S. to the Aravalli direction which is generally N.E.--S.W. A similar swing-round is also seen in the case of the older Bijawar (Aravalli) rocks and gneisses but does not take place till much further west ; the strike of these older rocks, therefore, does not everywhere coincide with that of the overlying Vindhyans but, like the latter, ultimately becomes N.E.--S.W. in the Aravalli range. The northwest border of the Vindhyan basin is of peculiar interest and will be considered in connection with the history of the Aravalli range.

LOWER VINDHYAN.

Distribution.—Outcrops of the Lower Vindhyan are confined to the margin of the irregular Vindhyan basin, and are exposed in three principal areas. Two of these fringe the " axe-haft " to the north and south, and are no doubt continuous beneath the more central tract of Upper Vindhyans ; the third occupies the western point of the " axe-blade ", in the neighbourhood of Chitor.

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[1] *Mem.*, LXII, 209 (1933).

From Sasaram, at the extreme eastern end of the outcrop of Vindhyan rocks, the Lower division is continuous at the base of the Kaimur scarp for 240 miles along the valley of the Son (the southern margin of the " haft "), disappearing at the Son-Narbada watershed, where the Upper Vindhyans sweep across into contact with Purana rocks. The greatest width of the Lower Vindhyan outcrop in this, its typical area, is 16 miles, but at some points on the lower reaches of the river it is less than two miles across. South and southwest of Sasaram, in the Palamau and Gaya districts, small inliers of the Lower Vindhyans crop out beneath the alluvium and the Upper Vindhyans respectively.

Westward from Sasaram, along the north side of the plateau (the northern margin of the " haft "), Lower Vindhyan rocks emerge from beneath the Upper Vindhyans in some of the valleys, but soon disappear, and at the lowest level, where the Ganges washes the base of the plateau at Chunar, only the Upper group is exposed. The concealment here of the Lower group is probably a result merely of a depression in the main axis of the basin, for further west some of its beds reappear beneath the Kaimur sandstone of the Upper Vindhyan as it rises towards the granite mass of Bundelkhand.

The appearance of the Lower Vindhyan under the northern scarp of the Kaimur range in southeastern Bundelkhand is in every way more irregular. From Chebu, close to the Jumna, the beds are seen at intervals below the scarp for 160 miles westwards as far as a point beyond the Dhasan, the principal exposures lying between this river and the Ken (Cane). East of the latter river, the older beds are visible only in the deeper gorges and are totally concealed for long distances where the Upper Vindhyans pass over them on to the granite. Around Tirohan the Lower beds are freely exposed, but where the Jumna first touches the rocks of the plateau, a few miles above Allahabad, the Upper Vindhyans are at water-level.

From about ten miles north of Chitor, the third of the principal exposures of the Lower Vindhyan curves southward to the Deccan Trap and thence eastwards along the northern edge of the latter, in the form of a narrow outcrop with irregular boundaries and one or two interruptions, to a point about 25 miles southeast of Jhalra Patan.

Besides these three principal exposures, Lower Vindhyan beds have been recognised in southeastern Rajputana between Malarna and Karauli in small separated outcrops.

General character.—The classification of the Lower Vindhyan lacks the definiteness of that of the Upper group. The zones of subdivision are not well marked, and all members of the series are not present in every section, the irregularity being due partly to thinning-out and partly to lateral change. The conspicuous want of constancy in the case of the first beds laid down is due to the unevenness of the floor of older rocks upon which they were deposited. Conditions of sedimentation became more uniform as the irregularities of this floor became filled up and smoothed off, and as the area of deposition became enlarged by gradual subsidence. The variability and inconstancy of the Lower Vindhyans, as compared with the striking persistence and uniformity of the Upper group, are probably the result, partly of the vulcanicity and partly of the preliminary oscillatory earth movement, which preceded the general regular subsidence that accompanied the steady accumulation of the Kaimur, Rewah and Bhander sediments.

(i) THE SON VALLEY.

Mode of occurrence.—The Lower Vindhyan rocks of that part of the Son valley which traverses Baghelkhand lie along the denuded northern flank of a synclinorium in which the chief rocks involved consist of Bijawars and Archaean gneisses.[1] The river valley itself is occupied by a narrow band of Lower Vindhyan beds which underlie the Upper Vindhyan Kaimur Sandstone forming the conspicuous scarp to the north. A narrow strip of younger rocks, consisting mostly of Lower Vindhyan but including three separate outliers of the Upper group, has been involved in the synclinorium and extends for some eighty miles within the Bijawar outcrop. North of Agori, a large E.--W. fault has caused considerable displacement of the outcrops and has interrupted the continuity of the stages in the main exposure. A series of small faults of the same orientation have affected the boundary between the Lower Vindhyan and the Bijawar at and south of Agori.

Relationship to the Jungel Shales.—For the greater part of their lower boundary, the Lower Vindhyan sediments are in unconformable contact with either the Bijawar series or the gneisses, but within the synclinorium there intervenes, more especially along the southern margin of the narrow elongated strip of younger rocks, a set of beds between the latter and the Bijawars, and apparently intermediate in age. These beds, to which the provisional name of Jungel Shale series has been given, have been classed by some with the Lower Vindhyan and by others with the Bijawars; their precise correlation is doubtful, but they have been described in this work under the heading of Purana (p. 380). As we shall see, the various stages of the Vindhyans overlap each other successively towards the north, until the Kaimur Sandstone, the lowest stage of the Upper Vindhyan, is found resting directly upon the Bundelkhand Granite. The Jungel Shales would thus fit into this scheme of overlap, were they proved to be the lowest exposed stage of the Lower Vindhyans.

Subdivision.—The Lower Vindhyan beds, in which shale or limestone predominates, are everywhere sharply distinguishable from the Upper Vindhyan group which consists mostly of sandstone. In the Son valley, eleven subdivisions of the Lower Vindhyan have been recognised east of the Kanhar tributary,[2] and eight to the west, excluding the doubtful Jungel beds.[3] These subdivisions have been correlated as follows :—

West of the Kanhar.	East of the Kanhar.	
Rohtas Limestone	Rohtas stage .	11. Limestone. 10. Shales. 9. Limestone. 8. Shales and sandstone.[4]

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[1] H. B. Medlicott. *Mem.*, II, Pt. 1 (1859); F. R. Mallet. *Mem.*, VII, 1-129 (1871); R. D. Oldham, P. N. Datta and E. Vredenburg. *Mem.*, XXXI, 1-178 (1901).

[2] F. R. Mallet. *Mem.*, VII, 27 (1871).

[3] P. N. Datta. *Rec.*, XXVIII, 144 (1895).

[4] By R. D. Oldham, E. Vredenburg and P.N. Datta this zone was included in the Kheinjua, but J. B. Auden considers it far more characteristic of the Rohtas stage. *Mem.*, LXII, 166 (1933).

West of the Kanhar.		East of the Kanhar.	
Kheinjua stage	Glauconitic group	Kheinjua stage	7. Limestone.
	Fawn Limestone		6. Shaly sandstone.
	Olive Shales		
Porcellanites		Porcellanite stage	5. Porcellanic shales.
			4. Trappoid beds.
			3. Porcellanic shales.
Basal stage	Kajrahat Limestone	Basal stage	2. Limestone.
	Bleaching Shales		1. Conglomeratic and calcareous sandstone.
	Basal quartzites and conglomerates.		

In neither area are the stages separated from each other by well-defined horizons. They merely represent facies of deposits which pass into each other both vertically and horizontally, either by interstratification and thinning out or by horizontal replacement.

Thickness and structure.—Owing to the folding within many of the subdivisions, the total thickness of the Lower Vindhyan cannot be accurately estimated, but near Agori, excluding the doubtful Jungel Shales, it is probably over 3,000 feet; thirty miles to the west it diminishes to about 1,000 feet, but still further west, in western Rewah, the thickness greatly increases. The maximum sequence of the Lower Vindhyan probably lies somewhere beneath the central part of the Upper Vindhyan exposure to the north. Contortion and disturbance are frequent but very local in character and due to some extent to the flagginess of the strata; these irregularities are more noticeable in the shales. Nevertheless, the series has a general northerly dip, from the older towards the newer rocks and, in a general way, the inclination decreases in amount from south to north, the upper members of the group being thus less inclined than the lower; near the ancient Bijawar slates the dip is often nearly vertical.

Mode of deposition.—The Lower Vindhyan of this area rests with a pronounced unconformity upon the Bijawars or the gneiss, out of whose debris their lower beds have been partially formed, and is mainly a shallow-water series. Before the end of the period, and following a stage of volcanic activity, there was a short interruption due to elevation resulting in alternating sub-aqueous and sub-aerial deposition.[1] Slight subsidence followed, resulting in the deposition of the Rohtas Limestone. A more permanent elevation succeeded and the shallow seas became the flood-plain areas of the early Upper Vindhyan period. The marine nature of the limestones in the Lower Vindhyan is shown by their thickness and excellent bedding. The marked parallelism of the bedding in the main limestones is an indication of quiet deposition and the absence of currents, waves and detrital accumulation, but their close association with sub-aerially exposed beds and beds with recognisable shallow-water characteristics, is a proof that conditions were never those of deep water. This is confirmed by the presence of bedded tuffs, which are most likely off-shore marine deposits formed in the vicinity of volcanoes along a continental margin.

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[1] J. B. Auden. *Mem.*, LXII, 220 (1933).

Jointing, and Sandstone dykes.—The Lower Vindhyan rocks, like those of the Kaimur, are strongly jointed, some of the joints having been formed soon after sedimentation as a result of contemporaneous movement. The latter phenomenon would also explain the presence of interformational conglomerates and sandstone dykes.

Basal stage of the West.—The basal stage of the west is inconstant as a result of original capricious sedimentation, and consists of a variable sequence of conglomerates, breccias, brown quartzites, slates, bleaching shales and lenticular limestones. The most usual succession is that of basal sandstones and conglomerates, made up of material from the underlying formations, passing up into shales with lenticles of limestones, and finally into a massive limestone which is locally very thick, ranging up to 2,000 feet. The characteristic basal conglomerate grades into pebbly and gritty quartzites or sandstones and, through these varieties, into pebbleless quartzites or sandstones, some of which show current-bedding. In these basal beds, which in some sections reach a thickness of 400 or 500 feet, the pebbles, averaging less than an inch across but ranging sometimes up to seven inches, are of the same type and character as those found in the Jungel beds, a resemblance which would support to some extent the assignment of the latter beds to the Lower Vindhyan. A large number of the pebbles consist of red jasper, derived from Bijawar rocks, and the rest of quartzite, vein-quartz, chalcedony, banded black slate, and black and brown shale, often bleaching. Some of the pebbles are composed of rocks of Lower Vindhyan aspect and suggest the existence of local contemporaneous elevation and erosion. Near Tarka, the conglomerate is replaced by an angular breccia, evidently a scarcely disturbed ancient talus deposit. The pebbly quartzites are in places permeated by vein-quartz.

The next beds above the pebble beds and quartzites are frequently black laminated, bleaching shales, which in places contain beds of earthy or dolomitic limestone in " pillows ", as well as brownish green sandstones derived from the Bijawars. Sometimes the shales are missing and the sandstones or quartzites, containing thin stringers of siliceous limestone, are directly succeeded by the Kajrahat Limestone.

The Kajrahat Limestone is sometimes coarsely crystalline but more usually finely crystalline or microcrystalline, well-bedded, and permeated by silica in veins, sills and amygdales. The limestone thins out in a curiously rapid way ; eastwards from Billi, it disappears completely in a distance of twelve miles, but is replaced apparently by a thin metasomatised band of chalky white siliceous rock.[1]

Basal stage of the East.—In the eastern section, the conglomeratic bed vary from a coarse, thick-bedded conglomerate, composed of slightly rolled fragments of the underlying older rocks from six to eight inches in diameter, to a coarse sandstone with pebbles of quartz. The limestone, No. 2, which is capricious in distribution, is for the most part hard and siliceous. These basal beds are only known definitely in the Son valley, though sub-stages 1 and 2 have been doubtfully identified in the outliers near Sasaram.

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[1] P. N. Datta records a similar passage of the Rohtas Limestone into a fine-grained green shale which, on exposure to air, turns a bluish chalky white (*Rec.*, XXVIII, 149 (1895)).

Porcellanite stage.—The three succeeding sub-stages of the eastern section are merely local modifications of the same deposit, the so-called " trappoid beds " being only coarser variants of the porcellanite. The Porcellanite stage as a whole, over 300 feet thick in the Agori region, consists of silicified or porcellanised tuffs, shales, sandstones and arkoses, but also includes unsilicified forms of the three last-mentioned rocks and, near the base, local conglomerates. Auden calls attention to the fact that some of the porcellanites are of epiclastic origin, especially the banded types and the green, translucent, thin-bedded types ; in the Agori area these varieties are the most common facies, and occasionally show ripple-marking. In clearly recognisable forms of the tuffs, plagioclase (between albite and oligoclase) is present almost to the exclusion of orthoclase, although analysis shows a higher percentage of potash than of soda.

The predominant and typical member of this stage is a hard, fine-grained, porcellanic rock, varying in colour from almost black to a pale green, and breaking with a conchoidal fracture into extremely sharp-edged splinters. The latter feature of the rock, combined with its evenness of grain, made it a favourite material with the men of the Stone Age in this region ; many singularly perfect specimens of large-sized axes and choppers as well as small flakes have been found. Associated with these fine-grained rocks are others to which a porphyritic aspect is given by the presence of small fragments of felspar and quartz ; in addition are fragments of more or less devitrified glass, grains of microcrystalline rhyolite and abundant pieces of pumice, often of comparatively large size. In the eastern area hornblende is a common ingredient and is not unknown in the west. In places, fragmentary material bulks so largely in the rock that the latter assumes a " trappoid " appearance, but it has been shown that both the trappoids and most of the porcellanites are rhyolitic tuffs of varying coarseness.[1] The homogeneity and compact nature of the porcellanites are the result of secondary crystallisation of quartz. The debris in both forms is angular and irregular in outline. In one locality in the eastern section, between Japla and Kutumbah, sheets of felsite—probably intrusive sills—have been found, and indicate the proximity of a centre of eruption. These truly igneous rocks are genetically related to the tuffs, all their constituent minerals being identical with minerals found in the latter.

Porcellanitic rocks are found interbedded both above and below that portion of the Lower Vindhyan specifically so named. The boundaries of the stage are, therefore, very indefinite, and the thickness is difficult to estimate. The latter near the western border of Rewah State cannot be less than 800 feet ; in the Agori area it is over 300 feet. When well developed and well exposed, the outcrop of this stage forms a band of low hills covered with a forest of the Incense tree (*Boswellia thurifera*), known in the vernacular as the *salai*.

The Porcellanite stage represents an original marine formation deposited within the vicinity of volcanoes, and corresponds probably to the Malani rocks of Rajputana. East of Jamual, the stage is cut out by a strike fault. Between that village and Hurma, it is represented by the shales which are elsewhere intercalated among the typical hard porcellanites and have replaced them, making it difficult to separate this stage from the one below and the one above. West and east of this shaly stretch, the stage increases in thickness and becomes coarser in type—indications of an approach in either direction towards the centres of volcanic activity from which the ashes were ejected. As we have seen, the existence of a volcanic centre to the east is confirmed by the presence of true igneous sheets. The fact that the exposures of the Porcellanite stage in the outliers forming the centre of the Son synclinorium seem to be less in thickness and on the average finer in grain than they are along the river bed is to a certain extent, an indication that the volcanic centres lay to the north of the Son, *i.e.*, in the direction of land, rather than to the south.

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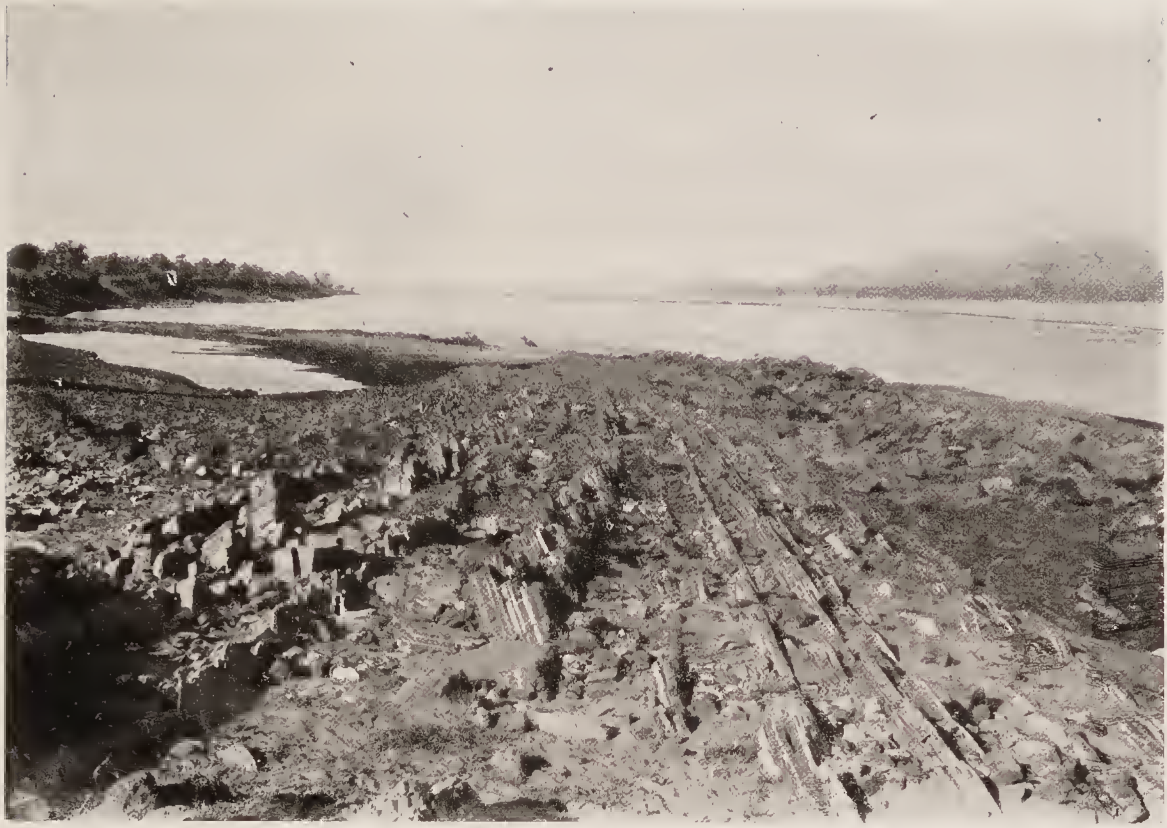
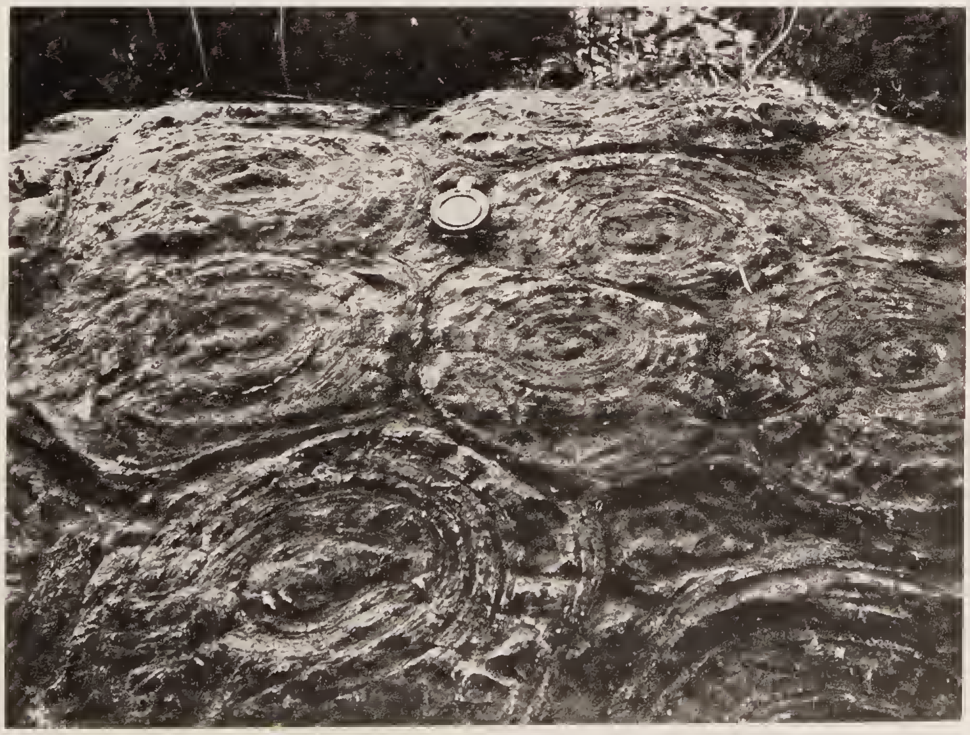
[1] J. B. Auden. *Mem.*, LXII, 153-54 (1933).

Kheinjua stage.—The Kheinjua stage, named after some hills south of the Kaimur scarp at and beyond the western boundary of Rewah State, corresponds to sub-stages 6 and 7 of the eastern area. Its rocks are principally shales and sandstones but limestones are occasionally found. West of Ramnagar, for instance, there are three thick bands of limestone which thin out eastwards and cease to form continuous bands. In the Agori area the sequence, as established by Auden, comprises a basal zone, over 100 feet thick , of very characteristic, fine-grained, olive-green shales with cuboidal or pencil fracture. These are succeeded by some 250 feet of siliceous and cherty limestone, slightly dolomitised, and weathering to a fawn colour. The weathered surface of the rock is pitted and marked out by the chert which occurs in irregular patches and parallel bands ; locally, the weathering is spheroidal with concentric alternations of limestone and chert. The bedding is coarse, from two to three feet thick, and individual bands show crumpling. Westwards, this Fawn Limestone , as it has been named, splits up and becomes interbedded with olive-green and blue shales. East of Agori, the limestone of sub-stage No. 7 remains a conspicuous feature, forming a central band some 20 feet in thickness, in the midst of the shales and sandstones.

In the Agori area, the Fawn Limestone is succeeded by a characteristic group over 300 feet thick marked by the presence of glauconite. This is a varied sequence of glauconitic sandstones, quartzites, pebbly grits, sandy shales, conglomerates, breccias and thin limestones, the last-mentioned rocks occurring near the base, just above the Fawn Limestone, imbedded with current-bedded quartzites. The bedding is markedly lenticular, seldom more than six inches thick in the silty impure sandstones, but attaining six feet in the case of the conglomerates and more indurated sandstones or quartzites. Ripple-marks and sun-cracks are abundant throughout the whole stage, rain-prints have been recorded, and the quartz grains in some of the sandstones show wind-rounding. Ripple-marking, sun-cracks and rain-pitting may often be observed on the same slab of rock. These features prove that, if sedimentation took place under marine conditions, as the presence of glauconite seems to indicate, the water was very shallow and must frequently have been drained, exposing the silts to the air ; the rounding of quartz grains points to an arid or semi-arid climate. In the sandstones, which are arkosic glauconite often occurs in pellet-shapes, perhaps due, as suggested by Auden, to the rolling and collection of clay material on the sea-floor and its incorporation in the form of pellets with normally deposited silts. Glauconitisation may have taken place before, during or after burial, but the habit of the mineral does not suggest derivation from pre-existing glauconitic sediments. The presence of glauconite in this stage of the Lower Vindhyan also provides some measure of support for the view that the period was not lifeless and belongs to the early



BANDED PORCELLANITES, LOWER VINDHYAN.



SPHEROIDAL FAWN LIMESTONE, LOWER VINDHYAN.

J. B. Auden, photos. *G. S. I., Calcutta.*

Palæozoic, since the mineral is formed in most cases in association with organic matter ; its alteration product is limonite. Of the Kheinjua conglomerates vein-quartz and red jasper are the main constituents ; the breccias include fragments of porcellanite.

Rohtas stage.—The uppermost beds of the Kheinjua stage pass up through calc-nodular shales into the most typical member of the succeeding Rohtas stage, which is a thin-bedded, flaggy limestone. The calc-nodules and shales, sub-stage 8 of the eastern section, are repeated above the limestone, near the top of the stage. The fine, parallel, grey and black banding of the shales passes also through the limestone nodules, which vary from six inches to three feet in diameter and occur isolated or in strings ; at the same time, the shales above and below the nodules show arching. As an explanation of this apparent inconsistency, Auden suggests that the nodules , in part at least, were formed contemporaneously with the deposition of the shales and that, once formed, they acted as concretionary centres for the deposition of carbonate, which continued for a short time after the nodules had been buried by the shale.[1] Some of the nodules have a septarian structure of radiating fissures. The shales are often black in colour and around Bijaigurh have been mistaken for coal.[2]

The chief feature of this stage is the limestone, which at Rohtasgarh is said to be 700 feet thick. An analysis of this rock shows 84 per cent. of $CaCO_3$, less than 3 per cent. of $MgCO_3$, and something like 10 per cent. of SiO_2 ; the stone is used for cement manufacture as well as for lime-burning and building stone. It is in this limestone that the sacred " Gupta " cavern of the Durgauti (Doorgowtee) valley exists. The bedding in both the limestones and shales of this stage is generally thin and markedly parallel, in this way contrasting with the lenticular bedding of most of the beds in the Kheinjua stage and with the thicker bedding of the Kheinjua limestones. Typically, the bedding of the Rohtas Limestone is from three inches to a foot thick. In both limestones and shales the prevalent tints are grey, blue, pink and orange. It has been suggested that the conditions of deposition of the Rohtas Limestone may have resembled those obtaining today at the Bahama Bank, where almost pure calcareous ooze is laid down on very shallow marine flats of wide extent.[3] Towards the top of the stage, silicification of the limestone is sometimes strongly pronounced. Near Rohtas, in the middle of the stage, is a thin-bedded limestone with small scattered crystals of blue and purple fluor-spar.

In the eastern section of the Son valley, above the principal zone of limestones is a band of shale which extends as a well-marked feature for a short distance into Rewah State, where it is 300 feet thick and in places in direct contact with the Kaimur Sandstone of the Upper Vindhyans. Further west, exposures are scanty but still further west this shale band is recognisable though reduced to a small thickness. In the Agori area, the top of the Rohtas stage consists in some places of black, papery, carbonaceous shales.

The total thickness of the beds assigned to the Rohtas stage is fairly uniform in the eastern section and in the country west of Rewah, but in the intermediate tracts it varies largely. The maximum thickness of the stage is attained near the western limit of Rewah State and probably exceeds 1,500 feet.

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[1] *Mem.*, LXII, 167 (1933).

[2] F. R. Mallet. *Mem.*, VII, 50 (1869).

[3] J.B. Auden. *Mem.*, LXII, 166 (1933).

(ii) BUNDELKHAND.

Position.—The Lower Vindhyans of the Son valley, as we have just seen, border the southern margin of the Kaimur plateau of Upper Vindhyan rocks, stretching from near the neighbourhood of Murwara in Northeast Jubbulpore to Sasaram. The northern limit of this Upper Vindhyan outcrop is also fringed for about half its distance with Lower Vindhyan deposits, which extend from one end of Bundelkhand to the other, and are no doubt continuous beneath the younger group with their fellow deposits of the Son valley.

Sub-division.—In Bundelkhand the Lower Vindhyans have been sub-divided as follows :—

5. Tirohan Limestone, and breccia.
4. Pulkoa Shales[1].
3. Dalchipur Sandstones.
2. Semri Limestone and Shales.
1. Semri Sandstone.

These stages are not all represented in every section. In the easternmost exposures, only the Tirohan Limestone and what is believed to be a representative of the Semri Sandstone are seen, while at the western end of the exposure the Dalchipur Sandstone is the only member of the group present. The Semri Sandstone is well developed in the middle of the area, in the vicinity of the Ken river ; westwards and eastwards it diminishes in importance and beyond the Dhasan river westwards it has not been definitely recognised.

Semri Sandstone.—The most interesting feature of the Semri Sandstone is the fact that it contains grains of glauconite. Eastwards it is traceable into relations with a band of flaggy sandstone, which near Panna gives place to a cherty bottom rock, more like an indurated shale than a sandstone, coating the old granite floor. A good exposure of the Semri Sandstone stage is seen at the Pathar Chauki waterfall ; here the chert band is about 150 feet thick and is surmounted by an additional 30 feet of thick-bedded, highly indurated sandstone, the presence of which is the cause of the waterfall. This cherty band is largely a detrital rock composed of quartz-sand, felspar grains and characteristic glauconite. Cherty segregation in many forms—spongy, pisolitic, amygdaloidal or disseminated—gives the bed a peculiar aspect. A common form of the rock in the Panna diamond mines is a semi-vitreous sandstone or pseudo-quartzite of a greenish tinge, the result of local diffusion of silica. In Panna State, beneath the chert band, is another harsh sandstone in relatively thick beds but of very small aggregate thickness ; it is often conglomeratic, owing to the presence of small scattered pebbles of grey or white quartz, and rests upon jaspery rocks of the Bijawar series.

Semri Limestone and Shales.—The blue Semri limestone and the overlying sharply-jointed, dark blue, slaty shale are also well developed at the Ken river and diminish in the same way as the sandstone stage westwards and eastwards ; westwards, these beds die out a little earlier than the Semri Sandstone and cannot be traced beyond Shahgarh. They are fully exposed in the valley of the Semri and are seen in the gorges of the Ranj and the Baged (Boghin), but are absent at Karwi. In Panna, the shales are remarkable for their coal-black colour, which has caused them to be mistaken for coal, and also contain large lenticular limestone concretions. There is an obvious resemblance in the description to some of the Rohtas beds of the Son valley.

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[1] The original name was "Pulkoa Schists".

Dalchipur stage.—The coarse pebbly sandstones of the Dalchipur stage whose most easterly exposure is near Chopra[1], increase in thickness and importance westwards, as the two lower stages decrease.[2] The stage ultimately overlaps the Semri Shales and comes into direct contact with the Semri Sandstone ; at the western end of the area it is the only member of the series represented. In places conglomerate occurs at the base and is prominent on the Dhasan river, its pebbles consisting of quartz or of Bijawar rocks.

Pulkoa Shales and Tirohan Limestone.—The two uppermost members of the succession are described as comprising thin, sharply-bedded, fine-grained limestones of very variable composition, both in chemical and mechanical ingredients, and flaky, siliceous shales, grey in colour but weathering or bleaching white. There are complete vertical and horizontal transitions between the two types. In one form or other, as shale or limestone, these beds are found from the eastern to within a short distance of the western end of the outcrop, being, like the Rohtas stage of the Son area, the only constant assemblage of the series. The Pulkoa Shales, named after Pulkoa (Palkua) Hill, are described as generally thinly laminated, having a foliated aspect, often intensely hard and jaspideous and usually breaking into angular cuboidal pieces.

Tirohan Breccia.—The limestone in Bundelkhand, unlike that in the Son is usually overlain by a siliceous breccia composed apparently of thin layers of agate, chert and jasper, shattered and re-cemented by sintery or hyaline silica. This breccia, which on Panwari Hill southeast of Tirohan attains a thickness of 40 feet, is not only adherent to the limestone but also fills cracks in its upper surface. It is not a detrital deposit and is very different in character from a breccia-conglomerate which is often found at the base of the Kaimur Sandstone. The Tirohan breccia is a contact rock which is probably of auto-clastic derivation and is conjectured to have been the intermediate home of the Panna diamond, the original source probably being the basic intrusives mentioned below (p. 511) ; large pebbles of the Tirohan breccia are abundant in the conglomeratic diamond bed of the Rewah shales (Upper Vindhyan) at the Panna mines and are broken up in the search for the gems.

Overlap at Karwi.—In the neighbourhood of Karwi, according to Medlicott, the Semri Sandstone is the only stage found beneath the Tirohan Limestone and contains layers of dense, fine limestone. The sequence here has been examined by Auden who depicts diagrammatically, as follows, the successive overlap from south to north, on to the fresh granite of the Bundelkhand tract :—

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[1] The village lies between Baragon and Kupe.

[2] H. B. Medlicott. *Mem.*, II, 9, 29 (1860).

North. South.

Chitrakot hill.	*Bihara hill.*	*Sangrampur hill.*	*Kohi hill.*
Kaimur Sandstone.	Kaimur Sandstone.	Kaimur Sandstone.	Kaimur Sandstone.
(*880-foot level*)			
	Glauconitic flags. Pellet limestone.	Glauconitic flags.	Tirohan Limestone.
	(*830-foot level*)	Pellet limestone.	Glauconitic flags.
Granite.			
		(*775-foot level*)	
	Granite.		Pellet limestone. Limestone with glauconite.
		Granite.	
			(*510-foot level*)
			Granite.

The Tirohan Limestone in this section, some 300 feet thick, with its flat strings of chert, resembles the Rohtas in its pink and orange tints and fine horny texture ; it is, however, somewhat more thickly bedded, the regular and almost perfectly horizontal beds ranging from one to three feet thick. Its correlation with the Rohtas is made almost certain by its superjacency with regard to glauconitic flags and limestones which, there seems little doubt, are the equivalents of the higher portions of the Kheinjua stage south of the Son. These soft, easily-weathering flagstones are similar to those in the Son valley Kheinjua and overlie a pellet limestone—a pisolitic rock made up of what were probably rolled pellets of limestone, subsequently silicified, in a matrix of glauconite and chalcedony. In places, this rock contains fragments of fresh felspar, angular and rounded fragments of vein-quartz, and lenticles of porcellanite, from one to two inches thick and several feet long, recalling a glauconite-porcellanite rock found in the Son valley at Burma. The lowest beds exposed in the Karwi area are some 20 feet of horny limestones containing angular fragments of fresh felspar and often glauconite.

As shown in the above diagram, the granite floor evidently continues its slope towards the south, and there has been progressive overlap in the Lower Vindhyans from south to north ; the full thickness of the series lies perhaps below the Kaimurs to the south. Auden received the impression that the slope indicated by the heights of the Pellet limestone in this section is more or less equal to the original sedimentation dip and was presumably sufficient to allow the rolling-down of unconsolidated limestone with the production of a pellet structure. The Semri Sandstone, more than the succeeding stages, is, therefore, limited in a northern direction by this granite slope upon which it was deposited. Consequently, as we have seen, in some of the outliers that stretch northwards beyond the main line of escarpment, such as the detached hills of Ajaigarh and Rajgarh, a Kaimur stage of the Upper Vindhyans rests directly upon the granite surface. The freshness of the granite and also of the felspar fragments in the bottom beds of the Lower Vindhyans is an indication of a dry climate.

Correlation with the Son valley sequence.—The precise correlation of the subdivisions of the Lower Vindhyan in Bundelkhand with those in the Son valley is uncertain, but the Pulkoa Shales and Tirohan Limestone appear to correspond to the Rohtas, and the remainder of the beds mostly or entirely to the upper parts of the Kheinjua. Basic intrusives are recorded which, although penetrating the Lower Vindhyans, appear to stop short at the Kaimur; some of these are typically doleritic but others are more basaltic in character. They may represent the primary source of the Panna diamonds[1].

Limits of deposition.—Both in the Son valley and in Bundelkhand, there are indications that the present limit of the Lower Vindhyans is not very far from that of their original extension. This is especially true in the case of Bundelkhand: for the original limitation of deposition is unmistakably exhibited by the overlap of the Kaimur group on to the gneiss and Bijawars. This is clearly seen on a large-scale geological map where, in all the northern prominences and outliers, the Upper Vindhyans are in direct contact with the older rocks, while in the deep-cut valleys draining from the south the Lower Vindhyans intervene. It is confirmed by the record of sections, where the Lower Vindhyans are seen to be baked against a sloping surface of Bijawars or granite. In the Son valley, the irregularity and coarseness of the lowest group show that it was deposited upon an uneven floor. The thinning-out of the subdivisions, except those of the Rohtas stage east of Bardi, and the absence of zones 6 and 7 and the sandstone of No. 8, are features perhaps due to this area having escaped the sedimentation which went on elsewhere. In the outliers to the south of the Son, the basal conglomerate is much thicker than it is in the main exposure.

Folding.—There is an increase in the intensity of the folding towards the south. This seems to be due in some way to the protective action of subjacent portions of the unyielding Bundelkhand Granite *massif* upon the northern margin of the Vindhyan basin, against the earth movement which went on during the Lower Vindhyan period itself and survived into that of the Upper. Throughout this area, the localised direction of the earth movement seems to have been from south to north.

(iii) SAUGOR DISTRICT.

A restricted outcrop of yellow or yellowish-brown shales at the foot of the hill which forms the western lip of the Deori gorge, east of Bhopal and two miles west of Deori village, in the Saugor district of the Central Provinces, has been doubtfully assigned by H. Walker to the Lower Vindhyan.[1] The shales are thin-bedded, slightly crumpled and, although distinctly micaceous, not very fissile.

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[1]. Mr. K. P. Sinor in his Diamond Mines of Panna State (1930) came to the conclusion that the diamantiferous rock of the Majgawan mines is similar to the diamantiferous Kimberley rock of S. Africa and that it occurs in the Kaimur sandstone as a pipe composed of volcanic agglomerate and tuff, the oval outcrop of the pipe measuring 1,500 feet × 1,000 feet. A bore-hole was driven to a depth of 242 feet in the rock yielding serpentinous decomposed products in which outlines of olivine are preserved. Siliceous and calcareous impregnations, also jaspidious pebbles, hard black quartzites and even sandstones were observed in some cores. According to these observations, a Post-Kaimur age would be ascribed to the intrusive source-rock of the diamond.

(iv) DHAR FOREST AREA AND NORTH BHOPAL.

Lower Vindhyan rocks are rather doubtfully displayed in one small exposure at the base of Bamnor hill, seven miles north of Amrawad in the State of Bhopal. They are sombre-tinted, micaceous and ferruginous shales, underlying the Kaimur Conglomerate with no apparent unconformity.[2] These occurrences lie to the east of Bhopal city. Iron-stained Vindhyan sandstones are also exposed in the Bhojpur quarry and its neighbourhood southeast of the city.[3] Some distance northwest of the city, and south of Jhalra Patan, some Vindhyan inliers below the Deccan Trap in the State of Khilchipur are described by Mr. D. P. Chandoke as having become quartzitic as a result of their contact with the basalt.

(v) THE CHITOR-JHALRA PATAN AREA.

Strike.—The edge of the western lobe of the great Vindhyan plateau, on the extreme west of which the famed fortress of Chitorgarh is built, curves round with the strike of the old rocks of the Aravalli range which, from N.E.–S.W. in northeastern Mewar or E.N.E.–W.S.W. in Bundi swings round at Chitor through N.–S. to N.W.–S.E., the Great Boundary Fault being to some extent concentric to the curvature.

General relationships.—Of the large tract of Vindhyan rocks between Chitor and Saugor a large part has been covered by the Deccan Trap. Along the southern and western margins of the uncovered portion from Chitor to Jhalra Patan, a great thickness of strata lies below the Kaimur Sandstone, differing from the Lower Vindhyan of both the Son valley and eastern Rajputana, and passing up with no discordance into a sandstone which is here the single representative of the Kaimur series, no basal conglomerate being present. Whether these beds correspond simply to the changeable Lower Vindhyan of other areas, as their position beneath the Kaimurs might lead one to infer, or whether the concordant succession with the Kaimurs signifies that they represent wholly or in part the unconformity seen elsewhere between the Lower and Upper Vindhyan, it is at present impossible to say. These pre-Kaimur beds, which have been described by Dr. Heron, occupy the lower ground to the west of the dissected plateau of Upper Vindhyans.[4]

Structure.—The pre-Kaimur Vindhyan beds of Chitor and Jhalra Patan do not exhibit that degree of compression seen further to the east. At their western limit they rest unconformably upon the gneiss and Purana formations, but along their southern margin the boundary is formed by the overlying Deccan Trap. In the latter section, the pre-Kaimur deposits are exposed in an anticline whose southern limb is for the most part concealed, but at Jhalra Patan and south of Rampura there are outliers of the Upper Vindhyan sandstone intervening between the older beds and the edge of the Trap.[5]

Northern corner of Malwa (North Indore).—In the neighbourhood of Kukdeshwar (Kukresor) and Rampura in north Indore, the beds, which are traversed by the Chambal river and are some 1,000 feet thick, consist of shale, limestone and sandstone, the last often conglomeratic near the base of the sequence and sometimes containing boulders that range up to three feet across. These boulders do not appear to include any of the volcanic beds found in the Son valley, and there are no traces of the Porcellanic beds. Furthermore, there are no important limestones to correspond with the Rohtas or other limestones of the more typical areas. The strata lie practically horizontal but with small, sudden warpings and puckerings; at least 300 feet are seen but the base is not exposed.

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[1] *Rec.*, XXXV, 54 (1907).

[2] *Gen. Rep. Rec.*, XXXIII, 106 (1906).

[3] D. P. Chandoke. *Amer. Journ. Sci.*, Ser. 5, XXXII, 218 (1936); *Quart. Journ. Geol. Min, Met. Soc. Ind.*, III, 138 (1931).

[4] A.M. Heron. *Mem.*, LXVIII, 69-80 (1936).

[5] C. A. Hacket. *Rec.*, XIV, 292 (1881).

The shales, known as the Suket Shales, here well exposed are comparatively soft and fissile, breaking into small cakes and not into splinters.[1] The colour varies from a drab or buff on the lower slopes of the Kaimur Sandstone scarps, to darker, chocolate, purple or green tints in the river-bed sections. Glauconite-bearing bands occur high up under the scarp, and harder, micaceous, flaggy beds and freestones, much used for building purposes, are found at lower horizons with some rare calcareous beds and thin layers of impure limestone. The most interesting feature of this area is the presence within the shales of what appear to be very small organic bodies in the form of concentrically wrinkled discs of carbonised substance, perhaps originally chitinous; these have already been described (pp. 498-99). Under the scarp the Suket Shales of this section have been protected from crumpling by the over-lying Kaimur Sandstone; away from the protective sandstone, the shales are apt to be considerably puckered.

Nimbahera area.—Further west, there is a more complete sequence, lying with no visible discordance beneath the Kaimur Sandstone and comprising the following[2]:—

	(in feet)
(4) Suket Shales	400
(3) Nimbahera Limestone	480
(2) Nimbahera Shales	150
(1) Khori-Malan conglomeratic sandstone and boulder bed	30-40

These beds give rise to no surface features, with the exception of the low ridge of the basal stage between Malan and Binota. Both the Nimbahera and the Suket Shales are scarcely ever seen, except in stream courses and, though the Nimbahera Limestone crops out extensively over a rough rocky country, the slabs of this stone project no more than a foot or two above the surface without even the formation of hillocks.

In this area the Suket Shales, warped into a set of narrow, gently undulating, N.-S. folds, are soft, fissile and fragile, often ripple-marked and frequently jointed, in colours varying from purple, grey, buff, greenish blue or chocolate to almost black. Resting conformably on the Nimbahera Limestone and passing up without discordance into the Kaimur Sandstone, they contain among their lower members hard, siliceous and micaceous flagstones, largely used for building purposes locally; occasionally the shales are calcareous. They are underlain by a distinctive, pale grey, fine-grained, hard, compact, regularly-jointed, non-crystalline, slabby limestone, occurring in beds from one to two feet thick, separated from each other by brown argillaceous or siliceous partings. It is extensively quarried as a building-stone and is almost fit for lithographic purposes. This limestone, to which the name of Nimbahera has been given, is continuous from near Jawad to Nimbahera and thence still further westwards at intervals as far as the undulating ground between Malan and Binota. It is from 200 to 450 feet thick and passes down through 30 feet of impure, deep reddish purple limestone into about 150 feet of brown or purple shale, known as the Nimbahera Shale, typically Vindhyan in aspect and, according to Dr. Heron, homogeneous, splintery and rather siliceous. Near the dislocation known as the Great Boundary Fault, this shale, where it abuts against the Bundelkhand Granite is crumpled and crushed, breaking into fusiform splinters. This shale stage passes down finally into a curiously local basement bed which, where present, is made up of dark purple or greenish brown sandstone or grit, with thin beds of fine ferruginous conglomerate, especially near the top. This basal stage, which is known as the Khori-Malan stage and resembles in every way some sandstones, quartzites and conglomerates found in Karauli and believed to form the base of the Lower Vindhyan in that State, is practically confined to the localities of Khori and Malan, where it forms a low but well-marked scarp, with a dip of 30°-35°, encircling the nearly flat trough of Nimbahera Limestone.[1] Near Binota the base of this stage is a boulder bed, 30-40 feet thick only, composed of large, well-rounded boulders of quartzite, some of them two or more feet in diameter, and pebbles of granite, gabbro and other rocks, in a purple, ferruginous, sandy matrix.[2] Towards Khori, the boulder bed becomes very thin and may in places be absent or represented by occasional, large, rounded, more or less isolated boulders. The sandstone is made up of angular grains of quartz, with a few minute flakes of mica, and grains of magnetite and haematite, in a cement which is mostly haematite. When present, the Khori-Malan stage lies upon either the Binota Shales (Aravalli) or the Jiran Sandstone (Delhi).[3] Elsewhere, it is the Nimbahera Shales which rest directly upon either the Binota Shales or the Jiran Sandstone.

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[1] *Gen. Rep.*, *Rec.*, XXXVIII, 66 (1909).

[2] A. L. Coulson. *Rec.*, LX, 168 (1927); A. M. Heron. *Mem.*, LXVIII, 74 (1936).

The Nimbahera Limestone may be the equivalent of the Tirohan or Rohtas Limestone of the Bundelkhand and Son areas, the Suket Shales corresponding perhaps to the shales found above the latter. Whether the glauconitic beds of the Kukdeshwar and Rampura area represent the top of the Kheinjua stage remains to be decided.

(vi) EASTERN RAJPUTANA.

Mode of occurrence and general character.—In Karauli and the neighbourhood of Gangapur in eastern Rajputana, several small isolated patches of Lower Vindhyan strata have been described by Heron, bordering outcrops of Upper Vindhyan.[4] The general trend of the topography and strike of the rocks are N. E.–S. W., the exposures of the Lower Vindhyan lying between two N. E.–S.W. strike faults of echeloned portions of the Great Boundary Fault of Rajputana. They form the lowest beds exposed in a double syncline of Vindhyan rocks and extend southwestwards to the Ranthambhor hills, on the Aravalli (Gwalior) quartzites on which they rest with a strong unconformity; it is only in this latter locality that their base is seen. The most prominent and constant member is a siliceous breccia identified as the Tirohan Breccia of Bundelkhand. Below this is the Tirohan Limestone with irregularly distributed quartzites and conglomerates at the base, but both the limestone and underlying beds are capricious in their development. No other members of the Lower Vindhyan have been recognised in this area.

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[1] *Gen. Rep.*, *Rec.*, LIX, 97 (1926).
[2] *Gen. Rep.*, *Rec.*, XLIV, 29 (1914) ; A. M. Heron. *Mem.*, LXVIII, 75 (1936).
[3] The " Delhi Quartzite" of Hacket.
[4] *Mem.*, XLV, 145—158 (1922).

Base.—Except at Sherpur, the Tirohan Limestone, wherever its base is seen is found to rest with no visible unconformity on pinkish quartzites ("Gwalior" quartzites) belonging to the Aravalli system, without an intervening grit or conglomerate. At Sherpur, an illuminating section shows at the base Aravalli (Gwalior) shales on which lies with a marked unconformity a coarse quartzite conglomerate, the material of all its boulders being identical with and evidently derived from the pink Gwalior quartzites of the adjacent scarps to the southeast. This conglomerate passes up into the Tirohan Limestone with cherty and shaly bands, and is, therefore, classified with the Lower Vindhyan; the passage bed between the conglomerate and the limestone consists of boulders in a calcareous matrix.

Tirohan Limestone.—The Tirohan limestone is exposed at intervals only dipping at low angles below the breccia. Its junction with the latter is never clearly seen and since the base and top are never clearly observed in the same section, its true thickness cannot be estimated; the maximum thickness exposed does not exceed 30 or 40 feet. The rock is dolomitised, and identical in appearance with the limestone at Tirohan. Interbedded shales and quartzites, and in one place a band of silicified oolite, have been observed. At Jirota, in western Karauli the chert and jasper from this limestone had evidently been used in the Stone Age, since cores, rough spear-heads, scrapers, and arrow-heads can be picked up in large numbers.

Tirohan Breccia.—The Tirohan breccia varies from a cryptocrystalline siliceous matrix containing sharply angular fragments of all sizes of pure white chert, to a banded yellow and white chert in which the bands, full of quartz-lined cavities, are twisted in all directions. Ferruginous varieties have been used for native iron smelting. The breccia is unstratified; its thickness is difficult to estimate but is not likely to exceed 200 feet. This rock sometimes rests directly on the conglomerate, at other times even the latter is absent and local coarse sandstones alone intervene between the breccia and the underlying Gwaliors. There is clear field-evidence that the breccia is autoclastic in origin. Cases have been observed in which the disruption and shifting of the cherty layers have not proceeded far enough to obscure their original continuity; there are in fact all stages between unbroken strips to rock-masses in which chert fragments are scattered without any visible mutual connection. Although the overlying Kaimurs also show some brecciation, the Kaimur conglomerate is quite distinct from the breccia and is a stratified aqueous deposit. The collapse which caused brecciation is thought, however, to have commenced prior to the formation of the conglomerate, since the latter includes locally denuded portions of the breccia; the junction between the breccia and the Kaimur conglomerate is, in fact, an unconformable one.[1]

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[1] A. M. Heron. *Mem.*, XLV, 152-156 (1922).

Disappearance Southwestwards.—Along the strike of the Karauli exposures in a southwestern direction, the Lower Vindhyan is not present, as a recent survey of Bundi State has shown, unless the black shales and inconstant sandstone found beneath the Upper Kaimur Sandstone to the east of Bundi town are representatives of the Kheinjua stage, to which they have resemblances.

(vii) LOWER VINDHYAN BASIC DYKES.

The latest rock of the lower Vindhyan epoch in Rajputana and the Son valley seems to have been that of the basic dykes which have penetrated the Lower but not the Upper Vindhyan. Doleritic intrusions of this kind have been recorded by Auden, stopping short at the Kaimur Sandstone. These are mostly weathered, in one case producing the simulation of a sandstone dyke, but fresh rock is occasionally found, varying from a typical dolerite to more basaltic forms. The doleritic type comprises crystals of highly-zoned felspar (mostly andesine) and pyroxene, with interstitial patches of micrographic quartz and felspar. Among the pyroxenes, the rhombic varieties, showing considerable bastite formation, predominate over the augite which is less weathered ; ilmenite and pyrites are both present, and the interstitial patches are turbid with alteration products. In the basaltic variety, long slender phenocrysts of enstatite, considerably altered to bastite, occur in a groundmass of augite, zoned felspars (approximating andesine), iron ores, and a dark-coloured glass with small crystals of iron ore.[2]

A possible age for the Newer Dolerites of Singhbhum is Lower Vindhyan.

A few basic dykes of insignificant size but of similar composition have been noted in the State of Idar, in one case at least penetrating the Erinpura Granite. Most of them are too weathered to allow of classification, but they are all thought to be of the same age as the intrusions of western Rajputana. One of them, an olivine dolerite, shows traces of ophitic structure. Another has a gabbro-like arrangement of labradorite, diallagic pyroxene, olivine, and iron ore with which is associated biotite, and has produced with the invaded granite a hybrid rock characterised by large glistening poikilitic plates of biotite.

Possibly the outburst of basalt observed by W. T. Blanford between Lawa (Lowo) and Pokaran, near the boulder bed of probably Vindhyan age (p. 552) belongs to this suite, but the relations of the rock are not clear.[3]

As is the case on the southeastern side of the Aravalli range, the latest rock of the Lower Vindhyan epoch on the northwest seems to have been that of certain basic dykes, which are found penetrating all the rocks of the Marwar area including the Malani Granite and Rhyolite but which have not been observed in the overlying outcrops of Vindhyan sandstone belonging probably to the Upper division of that system. Some of these intrusions have already been described since they appear to have commenced before the beginning of the Malani epoch, and belong to the youngest of the three phases into which it has been provisionally found necessary to divide the basic dykes of the Aravalli region (see. p. 260).

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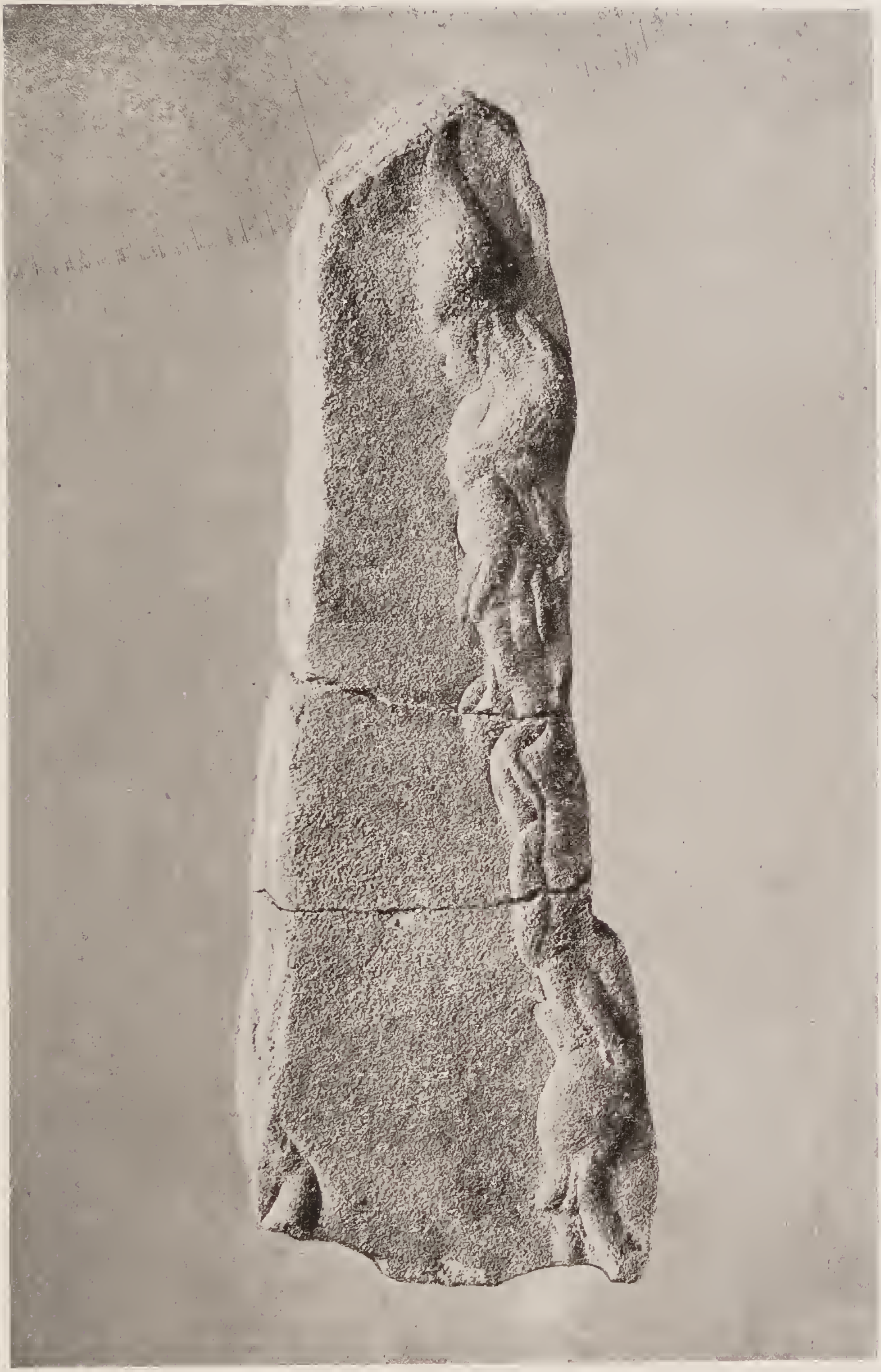
[1] J. B. Auden. *Mem.*, LXII, 191-192 (1933).

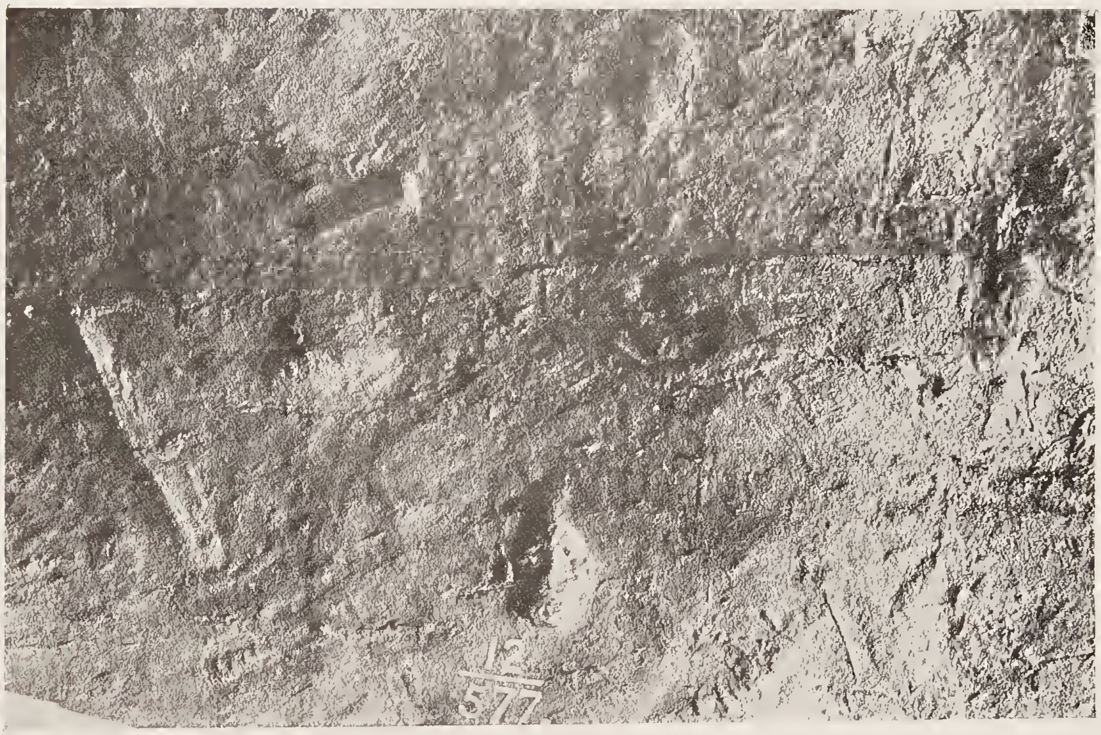
[2] Whether the olivine bearing Juturu dyke described in the previous chapter belongs to this suite or is older is not known.

[3] *Rec.*, X, 13 (1877).



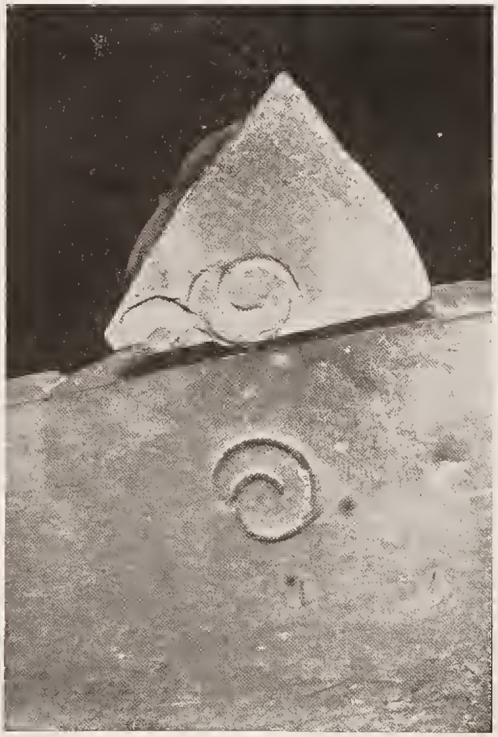
"CHORDOPHYCEOUS" TRACKS IN THE UPPER VINDHYAN.
(× 1/2·5 approx.)

E. W. Vredenburg, photo. *G. S. I., Calcutta.*



MARKINGS AND IMPRESSIONS OF ? ORGANIC LIFE IN VINDHYAN.
(× ·64 approx.)

E. W. Vredenburg, photo.



SPIRAL IMPRESSION ON
LOWER VINDHYAN LIMESTONE.
(Natural size.)

K. F. Watkinson, photo. *G. S. I., Calcutta.*

Some of the dykes of this youngest phase are definitely post-Malani but consist, like the others, of altered dolerite or diabase, made up of plagioclase, olivine and augite, with a small amount of biotite.[1] The majority of them in this region trend N.-S., but another system crosses them almost at right angles; they occasionally attain large dimensions, some of them being at least 200 feet wide. The dykes have taken advantage of joint-planes in the Malani lavas and granite and must have been injected, therefore, subsequent to the effusion and intrusion of these acid rocks, after an interval sufficient for the formation of such planes of fission. Usually the dyke rocks weather more readily than the surrounding rocks, and thus give rise to narrow steep-sided chasms which frequently form passes on the crests of the hill ranges.[2] Similar dolerites intrude the Malani granite of Sirohi State.[3]

UPPER VINDHYAN

Possibly organic impressions.—In the Upper Vindhyan, which follows so constantly upon the Lower, no determinable fossils have so far been discovered, but markings, impressions and shaped prominences are abundant at certain horizons, and some of them may be relics of organic life. In the accompanying plate are illustrated some of these markings, which are profusely scattered over the surface of sandstone slabs in the Sirbu Shales (Lower Bhander) of Bhopal.[4] Rare lenticles of vitrain found by Fox in carbonaceous shales—perhaps the Bijaigarh Shales—near the base of the Kaimur series, at Japla near Rohtasgarh, indicate the former existence of vegetable matter; five grammes of this bright coal on analysis gave :—65·62 per cent. of fixed carbon, 11·34 per cent. of volatile matter, 4·24 per cent. of moisture and 18·80 per cent. of ash, but much of the last-mentioned constituent was probably extraneous matter adherent to the coal particles.[5] No identifiable plant remains have been found, and the so-called "fucoid markings" are probably either concretionary structures or tracks of some obscure aquatic animal.[6]

None of the above-mentioned impressions has so far been sufficiently determined to afford any indication of the period to which the Upper Vindhyan should be referred. That it is older than the Upper Carboniferous is conclusively proved by the presence of pebbles of Vindhyan rocks in the Talchir Conglomerate. Judging from its thickness, which is over 12,000 feet, the Upper Vindhyan might well include an appreciable portion of the early Palæozoic.

While the Lower Vindhyan is on the whole argillaceous and calcareous, the Upper is essentially arenaceous; the change in fact from the fine-grained deposits of the Rohtas to the coarse sandstone of the Kaimur series is as sudden as it is widespread. In a few places, there is a visible unconformity between the Lower and Upper divisions of this system. Such discordance must not be confused with the twisting and contortion often seen in the Lower Vindhyan not far below a practically undisturbed outcrop of the Kaimurs ; such rucking is just as likely to have been the result of pressure subsequent to the Upper Vindhyan period upon rocks of different competency, and some of it may even be due to the weight of adjoining elevated masses upon yielding beds. The chief reasons for grouping these older and younger beds as divisions of the same system are : (i) the lack of discordance between the two in the majority of sections, and (ii) the fact that the older is invariably followed by the younger. The latter statement, however, does not apply to the presumed equivalents of the Lower Vindhyan found to the south of the gneissic barrier—*i.e.* to the Bhimas, Kurnools, and other formations.

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[1] T. H. D. La Touche. *Mem.*, XXXV, 25 (1902).
[2] *Gen. Rep.*, *Rec.* 1897-98, 36—37.
[3] A. L. Coulson. *Mem*, LXIII, 113 (1933).
[4] At Lilgar. See E. Vredenburg *Rec.*, XXXVI, 248-249 (1908).
[5] *Gen. Rep.*, *Rec.*, LXII, 35 (1929); C. S. Fox. *Mem.*, LVII, 26 (1931); J. B. Auden. *Mem.*, LXII, 216 (1933).
[6] B. Sahni. *Proc. 8th Ind. Sci. Congr.*, VIII (1921).

Distribution.—The Upper Vindhyans are found in an almost continuous but irregular outcrop from Chitor in the west to Sasaram in the east. A large and roughly square area—the " blade " of the " axe " mentioned earlier in this chapter—some 250 miles across its diagonal, and having its four corners at Achnera to the north (west of Agra), Chitor on the west, the Narbada valley opposite the Dhar State to the south, and a point north of Narsinghpur in the Central Provinces on the east, is all presumably occupied by Vindhyan deposits although, as already noted, a very large part of it is covered by the Deccan Trap of the Malwa plateau. From the neighbourhood of Saugor and Narsinghpur, a long strip—the " haft " of the " axe "—with a maximum width of 50 miles, continues eastwards for 340 miles to Sasaram in Bihar. The actual total exposure of the Vindhyan deposits, of which only a small proportion belongs to the Lower division, measures about 40,000 square miles, but an additional 30,000 square miles probably lie beneath the Deccan Trap, and further tracts of unknown area are concealed below the alluvial deposits of the Ganges, Jumna and Narbada. The Purple Sandstone of the Salt Range, lying below beds which have yielded Middle (or late Lower) Cambrian fossils, exhibits a noticeable resemblance to some of the Upper Vindhyan sandstones, especially those prone to a red colour such as the upper Rewah, the Upper Kaimur or the Upper Bhander.

The area occupied by Upper Vindhyan rocks, especially in their eastern extension, is well marked off from the surrounding country, both by the greater elevation of its plateau, and by the clearly cut escarpments by which it is almost everywhere bounded. The southern declivities, overlooking the Son and Narbada, are abrupt and precipitous, forming that long line of escarpment to which the name of " Vindhya " is more peculiarly applied. The " haft " of the " axe " is naturally divisible into three plateaux, each of which has for its floor one of the three great sandstones of the formation, the Kaimur, the Rewah or the Bhander. Over the edges of these plateaux the drainage makes its way in gorges and waterfalls, often of great beauty. Without exception the most prominent features of the Vindhyan area are its numerous escarpments. Along some of the lines of scarp, outlying hills are very frequent : it is on such eminences, whether partially or completely detached, that hill forts such as Rohtasgarh, Chunar, Chitor, Kalinjar and Gwalior, have been constructed.

Lower boundary.—Throughout a large part of its margin, the Upper Vindhyan lies unconformably upon either the Bijawar or Gwailor schists, both of supposed Dharwar age, or the Bundelkhand Granite or its Rajputana equivalent, the Berach granite. On the great granite tract of Bundelkhand, outliers of Upper Vindhyan are numerous and lie at considerable distances from the scarp of the granite; the lower Vindhyan is not represented in these outliers. In the eastern branch of the main Vindhyan basin, however, and in the Dhar State, the Upper Vindhyan rests in most cases with no apparent unconformity, upon the Lower Vindhyan. In eastern Rajputana, *i.e.*, along part of the cutting-edge of the "axe", an unconformity is seen at the base of the Kaimur, separating the Lower from the Upper Vindhyan, but there is a perfectly conformable sequence throughout the latter division, up to the highest horizon exposed, which is the Upper Bhander Sandstone. Some of the best examples of unconformity are to be seen in the three outliers south of the Son river, where rocks of almost certain Upper Vindhyan age rest upon vertical or steeply-dipping beds belonging to the Lower division of the system. In the Tirohan-Karwi area of Bundelkhand, the Kaimurs overlap the Lower Vindhyan in a northerly direction, and were deposited in a basin already largely filled in by Lower Vindhyan rocks.

Subdivision.—The following is a general classification of the Upper Vindhyan :—

Bhander series	Upper	Upper Bhander Sandstone.
	Lower	Sirbu or Samria Shales. Lower Bhander Sandstone. Bhander Limestone. Ganurgarh Shales.
Rewah series	Upper	Upper Rewah Sandstone
	Lower	Jhiri Shales. Lower Rewah Sandstone. Panna Shales.
Kaimur series	Upper	Upper Kaimur Sandstone. Kaimur Conglomerate.
	Lower	Bijaigarh Shales. Lower Kaimur Sandstone.

Character and mutual relationships of the subdivisions.—The Upper Vindhyan outcrop covers a very much larger spread of country than the Lower and, in a general way, is made up of several thick masses of sandstone with alternations of shale; the calcareous element is deficient, being represented only by a single limestone of importance. The subdivisions, especially those of the Lower Rewah, are not all of them present in every section. Nevertheless, the general composition and arrangement of the Upper Vindhyan rocks is strikingly uniform, and in spite of their obviously shallow-water nature, one of the most interesting and characteristic features of the group is the extraordinary persistence, over the greater part of the great basin, not only of the chief but also of most of the minor subdivisions. All are, for instance, represented both to the east and to the north of the mass of the Deccan Trap which has covered so much of the outcrop in Central India. The Lower Bhander and Lower Rewah sandstones are attenuated or absent in certain directions, but there is usually an equivalent increase in the thickness of the enclosing shales. Sometimes it is the great bands of shale which thin out and disappear, allowing the main sandstones to coalesce. In eastern Rajputana, along the northern corner of the Vindhyan basin, every division of the Upper Vindhyan, with the exception of the Bijaigarh Shales and Lower Kaimur Sandstone, can be recognised, in spite of incomplete exposure caused by the alluvial deposits which so copiously fill the longitudinal valleys excavated in the shale bands. At a distance of several hundred miles, the same subdivision can often be recognised at once by the peculiarities which distinguish it elsewhere.[1] The mutual relation between the sandstones, shales and limestones is an intimate one throughout. At the same time, while the passage upward from shale into limestone or into the great bands of sandstone is always more or less gradual and by interstratification, the change into shale at the top of the great sandstone beds is generally abrupt.

The beds of the lower stages are apt to show more change than those of the higher; the lower sandstones are more vitrified and the lower shales more indurated than the corresponding beds in the younger subdivisions. The reason for this is that the uppermost beds have never been overlain by younger deposits, nor, except along certain local axes, disturbed to any extent by earth movement; the Bhander series, for instance, seldom shows signs of any change. In most cases, not even the Gondwana beds are to be found in superposition upon the Vindhyan. Along local lines of disturbance, as for instance in the Dhar Forest area, the sandstones have been converted almost into quartzite and the altered aspect of the Vindhyans of this area is in contrast with the absence of metamorphism in the neighbouring Gondwanas. The presumed equivalents of these beds in the Himalaya show, as we should expect, much more alteration, a fact which does not diminish the difficulty in correlation.

Although made up chiefly of sandstones—deposits typical of the coarser kinds of detritus—the general fineness of the sediments which make up the formation is another remarkable feature. Widespread ripple-marking throughout the greater part of the system and frequent current-bedding bear witness to the shallow nature of the Upper Vindhyan waters, but pebble-beds are not of common occurrence among the deposits, with an exception in the case of the Kaimur Conglomerate, which is constantly present as a bottom bed all round the boundary in Bundelkhand. Perfect ripple-marks are often to be seen on the surface of bed after bed throughout a thickness of hundreds of feet. Other general characteristics are the predominant reddish colour of the rocks and the deficiency of the calcareous element. Generally, the Upper Vindhyan rocks yield a poor soil and their outcrops are frequently barren.

Kaimur series.—The Kaimur (Kymore) attains its greatest extension horizontally and vertically, at the eastern end of the Vindhyan area, and it is here specially that the lower subdivision of the series is developed. This is of small importance compared with the upper, but is well seen east of Agori along the broad, shallow, strike-valley of the Ghagar, which has been excavated out of the Bijaigarh Shales. The latter crop out in the scarp at either side and on the flanks of the imposing hill from which they derive their name. Eastwards they can be traced, sometimes by one thick band, sometimes by several bands alternating with sandstone, and are well exposed in the Durgawati (Doorgowtee) valley, but are not found at Sasaram. West of the Ghagar, the Bijaigarh Shales can be followed as far as Bardi (Burdhee), beyond which the Lower Kaimur Sandstone below and the Upper Kaimur Sandstone above form a single scarp. The thickness of the shales at Bijaigarh and in the Durgawati valley is about 150 feet. In places, the shales rest directly upon the Rohtas Limestone of the Lower Vindhyan, but elsewhere the Lower sandstone intervenes, and attains at Bijaigarh a thickness of 200 feet or more, thinning out east and west. The lower division of the Kaimur, therefore, must have been deposited rather irregularly or in patches.

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[1] F. R. Mallet, *Mem.*, VII, 48 (1869).

East of Agori, the Lower Kaimur Sandstone stage consists of two well-defined bands of fine-grained, markedly lenticular quartzite, forming two distinct scarps with an intervening band of shale which contains an interesting breccia and some porcellanite beds. West of Markundi, the shales die out and the two quartzite bands coalesce to form a single scarp.[1] The section east of Agori has been studied by Auden. Here, the lower gritty quartzite is generally more massive than the upper and includes lenticular patches of small pebbles, seldom more than half-an-inch in diameter and consisting mostly of vein-quartz but sometimes of ironstone ; current-bedding is locally common. This quartzite passes up into thinly-bedded, lenticular flagstones and mudstones, which show excellent sun-cracks and ripple-marks and are sometimes conglomeratic with ovoid lumps of black shale. Next come dark, micaceous, papery shales, with jet black, strongly-jointed, siliceous, and carbonaceous varieties, and thin bands of sideritic ironstone ; interbedded with the black carbonaceous shales, which readily bleach, are some strongly-jointed procellanites, some light-coloured, others black-banded. In a clear-cut channel or " washout " eroded by currents in these underlying siliceous shales lies the local Susnai conglomerate or breccia. This deposit, which swells from ten inches to seven feet within a distance of 20 feet, is composed of a gritty or quartzitic matrix, sometimes current-bedded, with rounded and angular fragments of porcellanite—derived no doubt from the immediately adjoining porcellanite of this stage—and a few of red jasper. The frequent and markedly angular habit of the porcellanite fragments, which gives the rock its breccia appearance, is probably a result of the strong jointing which such procellanites possess, while the gradual grading of the Susnai rock into gritty sandstone with a few porcellanite pebbles, and finally to a pebbleless gritty sandstone, confirms the conclusion—already indicated by the abrupt " washout " of the shales and the lenticular disposition of both the breccia and the underlying quartzite—that the rock is not autoclastic but epiclastic. The upper quartzite of this succession resembles the lower, except that its bedding seldom exceeds three feet, and forms a rim surrounding the main scarp of the Upper Kaimur Sandstone. The sand grains of both upper and lower quartzites are nearly all beautifully rounded and coated with a cement of secondary silica ; the rounding is almost certainly a result of wind action although the deposit itself is undoubtedly aqueous. Tourmaline is generally a very common constituent of the grains but felspar is absent.

The sandstones or quartzites of the Lower Kaimur pass up gradually into the Bijaigarh (Bijigurh) Shales. These are fine-grained, carbonaceous, micaceous, frequently pyritous, and contain occasional ironstone bands ; their upper horizon for ten feet or so have usually been bleached to red and yellow colours, due to the oxidation of pyrite with the formation of ferric oxides and sulphates, the latter appearing as a white efflorescence on the surface of the shale. The Bijaigarh shales are very brittle and typically affected by "pencil" fracture. The black varieties have been mistaken for coal; the actual presence of the latter substance is of purely academic interest.

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[1] J. B. Auden. *Mem.*, LXII, 171 (1933).

The only recorded occurrence of the Kaimur Conglomerate in the Son valley is about ten miles west of Badanpur, where four or five feet of it intervene between the Bijaigarh Shales and the Kaimur Sandstone; the pebbles here include a few of quartz but are, for the most part, ferruginous and almost hæmatitic, like those of the doubtful Lower Vindhyan beds in the Chimur-Mul area of the Central Provinces, and measure up to four inches in diameter. Along the northern margin of this part of the Vindhyan outcrop, the conglomerate is largely though unequally developed in Bundelkhand, where it is everywhere conspicuous by reason of the bright red jasper pebbles so prominent in it, presumably derived from the jasper bands so abundant in the neighbouring Gwalior formation; where the Kaimurs rest upon the Gwalior beds, the rock is a breccia rather than a conglomerate, the included fragments being quite angular. From Bundelkhand to Gwalior State the conglomerate is seldom entirely missing. In the latter uneven country, it is sometimes absent on higher ground though present in thick masses in the hollows; an interesting instance of this is seen near Duserai at the junction of the Par and Kaimur escarpments, where the pebbles of the conglomerate are seen piled against a steep bank of gneiss and Gwalior sandstone (see fig. 14).[1] Further west, in the Narbada valley southeast of Bhopal, both the conglomerate and sandstone have been recognised. In southeastern Rajputana, the Kaimur Conglomerate is intimately associated with a breccia belonging to the Lower Vindhyan, but is separated therefrom by an unconformity. It persists southwestwards into Bundi State where, although seldom more than eight feet thick and seen only to the north of the hills, it is a constant member of the series. In Mewar, further southwest, it is absent altogether, the uniformly fine-grained Kaimur Sandstone succeeding the Suket Shales with every appearance of conformity. In Karauli, northeast of Bundi, the thickness of the conglomerate is from six to 20 feet.

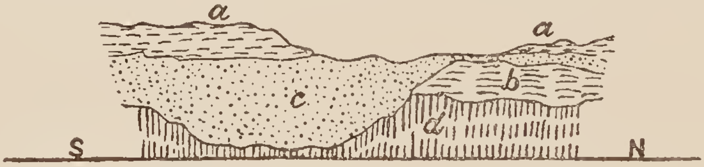

Fig. 14. Junction of the Vindhyan and the Par scarps, near Duserai. *a*, Kaimur Sandstone; *b*, Par Sandstone; *c*, Kaimur Conglomerate; *d*, Gneiss.

Like that of the Lower Vindhyan, the Kaimur Conglomerate is regarded as a shore deposit marking approximately the original limit of deposition in the Vindhyan basin. In the outliers and spurs north of the main line of the escarpment in Bundelkhand, the pebbles are much larger than they are in the deep valleys—like that of the Ken—that cut back a long way south of the main scarp[2]; this increased coarseness in a northerly direction indicates the former existence of a coast-line close to the present northern border of the Vindhyan formation. Further south, however, in the outliers south of the Son river, pebbles of quartz and jasper found in the Vindhyan sandstone reach a foot in diameter; this assemblage may correspond to the Kaimur Conglomerate which it, in places, resembles. In eastern Rajputana, where the conglomerate is often only a foot or two thick the pebbles range in size up to that of a walnut, and exceptionally to that of an orange[1] as often as not it occurs here as thin lenticular layers distributed throughout a thickness of from ten to twenty feet of coarse sandstone or quartzite.

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[1] F. R. Mallet. *Mem*., VII, fig. 6, 58 (1871).

[2] E. Vredenburg. *Rec*., XXXIII, 271 (1906).

The Kaimur Conglomerate is everywhere conspicuous by reason of the prominence therein of the bright red jasper pebbles derived from the Gwaliors or Bijawars ; it is typically seen on Pulkoa Hill near the river Ken in Bundelkhand, where the Vindhyans rest upon the Gwalior beds, as they do under Gwalior Fort, the rock has more the appearance of a breccia than a conglomerate. The amount of this easily recognisable jasper débris throughout such a length of outcrop and at such a distance from the nearest known area of Gwalior deposits, suggests the extensive removal of these rocks from the area now occupied by the uncovered gneiss. In eastern Rajputana, the Kaimur Conglomerate is composed of pebbles of white quartz, of red, black, brown and black-and-red striped jasper, and of white and black-and-white striped chert, lying in a scanty matrix of rather coarse grains of quartz. In Bundi State, the bulk of the pebbles also far exceeds that of the matrix ; the pebbles here are small and consist of white reef-quartz, red and black jasper, with fragments of shale, sandstone, felspar and white and black chert.[2]

The Upper Kaimur Sandstone—or Kaimur Sandstone as it is commonly called since it is in most places inseparable from what may be the equivalent of the Lower Kaimur Sandstone—is greyish, yellowish or pinkish and sometimes speckled with brown or brownish purple patches, in many cases spreading from the bedding planes and joints and due to the percolation of iron-bearing waters. It is hard and fine-grained, with minute specks of felspar. Like the other two great sandstones of the Vindhyan system, it possesses individual characteristics which distinguish it from the others. On the whole, the bedding is of moderate thickness. Sometimes this stage is flaggy and shaly, especially towards its base where also the quartz grains are mostly angular. Massive beds are abundant in the main scarp, ranging from five to fifteen feet across, and in the Pichhor (Pichaur) outlier on the Bundelkhand Granite to the southeast of Gwalior city attain a thickness of thirty feet without joints or bedding. In these sandstones of the main scarp, the grain is usually fine, and there is an abundant clay matrix between the quartz grains, many of which show wind-rounding[3] ; towards the top they become purer and quartzitic. Current-bedding is frequent, sun-cracks and ripple-marks are abundant at certain horizons, and rain-pitting is occasionally identifiable. The upper surface of the sandstone is very uniform but its lower surface has usually had to adapt itself to a very uneven floor ; a good instance of this is seen near Bastari (Bustori) in Gwalior, where an outlier of the sandstone stretches across and nearly fills one of the old valleys in the Gwalior series (see fig. 15).[4]

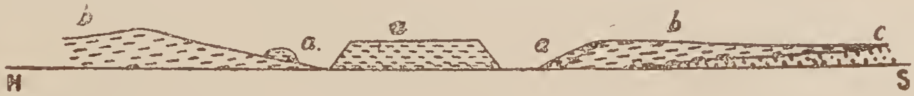

Fig. 15. Section near Bustori (Bastari). *a*, Kaimur Sandstone, *b*, Jasper beds of Gwalior series *c*, Par Sandstone.

In eastern Rajputana, along the northwestern boundary of the Vindhyan outcrop, the Kaimur is hidden beneath alluvium for some distance. Where exposed in this locality, it is a sandstone or quartzite, becoming in its higher horizon finer and whiter, flaggy, and spotted with pink; it is here, however, a very variable rock, with a thickness of about 1,000-1,200 feet, and is described as passing up into the Panna Shales.[1] The sandstone is exposed in the Bundi State, where it is in general fine grained, well jointed, and always red in colour; its top is not seen here.[2] In the Rampura area, between Chitor and Jhalra Patan, the Kaimur forms a very striking wall-like scarp, and is a quartzite rather than a sandstone, not unlike some of the Delhi quartzites, and breaks with a rough conchoidal fracture into knife-edged splinters;[3] towards the Deccan Trap boundary are innumerable outliers of this quartzite, lying upon the Suket Shales but at a much lower level than in the main scarp. In southern Rajputana, gritty and conglomeratic bands, obviously derived from the Berach or Bundelkhand Granite, are found at or near the top of the stage. Southwest of Mandalgarh the Kaimur Sandstone is divided into two divisions by a thin band of shales; in the upper, bedding is more prominent than jointing, while in the lower the reverse is often the case.[4] In Bundelkhand also, Vredenburg found it possible to distinguish between a thick-bedded lower division, 300 feet thick, and a thin-bedded upper division of 200 feet.[5]

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[1] A. M. Heron. *Mem.*, XLV, 160 (1917).

[2] A. L. Coulson. *Rec.*, LX, 168 (1927).

[3] J. B. Auden. *Mem.*, LXII, 183-4 (1933).

[4] F. R. Mallet. *Mem.*, VII, fig. 7, 58 (1871).

In the country east of Chitorgarh, the Kaimur Sandstone is disposed in long, narrow, fusiform outliers, separated from each other by anticlinal valleys of Suket Shales, the maximum dip not usually exceeding 15°. The outcrop of the Kaimur Sandstone is traversed by the Chambal river; above Bhainsrorgarh, the beds of quartzite, which here dip upstream, give rise to a series of small falls, whereas below the town where the dip is downstream and gentle the result is a succession of rapids.

From the Rewah sandstone the Kaimur rock is distinguished by its greater purity, by its more quartzite-like character, and by the more marked tendency it shows to form great flat expanses of bare exfoliating rock; in the Rewah rock jointing is more dominant, and there is a more copious division into cubical blocks.

The thickness of the Kaimur varies enormously. From a few feet it may swell to 300 feet. At Rohtasgarh, in the extreme east, it is estimated to show 1,300 feet and may have been thicker as it is now covered by no other beds. There is a magnificent section of this series in the deep and narrow gorge of the central Adh river. Westward along the Son valley, the Kaimur, represented by sandstone, most of it belonging no doubt to the Upper bed so named, becomes thinner and is reduced to less than 150 feet to the west of Badanpur; northwest of Katangi (Kuttungee),[6] the Lower Vindhyan inliers are in contact with the Rewah sandstone and the Kaimurs are absent. In Mewar the Kaimur is 100-250 feet thick, in Bundi 100-120 feet, and in Karauli not less than 100 feet. The Kaimur Sandstone makes a valuable building-stone and has been largely used in the Son Irrigation Works.

From a study of the Kaimurs of the Son valley, Auden concludes that they were deposited under fluviatile conditions like those which pertained to the accumulation of the Old Red Sandstone of Great Britain, which the Kaimurs so much resemble. The shallow seas, after the elevation which followed the Lower Vindhyan sedimentation, became flood-plain areas in inter-montane basins, upon which were deposited the Kaimur sands and silts, including material blown in by wind from the siliceous bordering regions, under a climate of seasonal rainfall and semi-arid conditions. This seasonal change and intermittent aridity are suggested, (i) by the freshness of the basement granite and of the fragments of felspar in the overlapping beds of the Vindhyans where they come close to the granite, (ii) by the conspicuous rounding of the quartz grains which is most marked in the Lower Kaimur Sandstone stage, but is present also in the Kheinjuas and the Upper Kaimurs and (iii) by the red and brown colours of the Upper Kaimur Sandstone, a feature repeated later in the Bhander Sandstone. Local swamp conditions caused the formation of the black ferruginous and carbonaceous shales of the Lower Kaimurs, but a final elevation of the whole area, with rejuvenation of the streams from the flanking mountains and consequent abundant supply of sediment, resulted in the deposition of the thick Upper Kaimur Sandstone in the river reaches.[1]

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[1] A. M. Heron. *Mem.*, XLV, 161 (1917).
[2] A. L. Coulson. *Rec.*, LX, 168 (1927).
[3] *Gen.*, *Rep.*, *Rec.*, XXXVIII, 66-67, (1909).
[4] A. M. Heron. *Mem.*, LXVIII, 93 (1936).
[5] *Rec.*, XXXIII, 267 (1906).
[6] A small village 22 miles N. N. W. of Jubbulpore, and not the town of that name in the Balaghat district, nor another in the district of Raipur.

Rewah Series.—The Rewah series is less constant than the other two and its stages are frequently missing ; its sediments seem to have been deposited upon a sloping floor of the Kaimurs. The Jhiri (Jheeree) Shales are said to differ from the Panna (Punna) in being softer, less regularly bedded, and mixed with numerous layers of soft earthy sandstone, but, like other shale bands of the Vindhyan, neither stage presents any constant distinctive characters. The junctions of the Panna Shales with the underlying Kaimur Sandstone, and of the Jhiri Shales with the underlying Lower Rewah Sandstone, show the customary sharpness, except in eastern Rajputana where the Panna Shales pass down imperceptibly into the Kaimur. The Lower Rewah Sandstone, except in eastern Rajputana and Gwalior, is but a local subdivision, and is not of the same continuity as the three great Vindhyan sandstones. When present, it is characterised by the frequency of pebbles and the occasional presence of clay balls. It is absent in the extreme east of the Vindhyan area, but is well seen near the debouchure of the Tons river. At Panna, both it and the Panna Shales are absent ; further west in Bundelkhand the Upper Rewah Sandstone lies directly upon the Kaimur Sandstone, while further west still the Upper Rewah is in contact with the Lower Vindhyan. The maximum thickness of the Lower Rewah in this region is about 530 feet, of which about 100 feet consist of the sandstone. Northwestwards, in Gwalior, all three stages of the Lower Rewah reappear, attaining a thickness of nearly 600 feet. They are also seen in eastern Rajputana along the southeastern flank of the Aravalli range, where the Lower Rewah Sandstone is well developed and forms a scarp little inferior to that of the Upper Rewah Sandstone, expanding into an undulating plateau northeast of Khadarpur. The thicknesses here are : Panna Shales—here not very distinctly laminated and breaking conchoidally into sharp flakes—150 feet ; Lower Rewah Sandstone 250 feet ; and the Jhiri Shales, with yellow, brown and red limestone in thick beds at their base, 500-600 feet ; giving a total of 900-1,000 feet. In Bundi State, the sandstone is sporadic and the Panna and Jhiri Shales are thin but persistent, well cleaved and jointed ; the younger of the two shale stages, here about 100 feet thick, contains limestone bands, not at the base but among the upper horizons near Indargarh. In Mewar, where the Lower Rewah Sandstone is absent, it is impossible to distinguish the boundary between the Panna and Jhiri Shales and the succession, varying in thickness from 150 to 350 feet, is best alluded to as the Rewah Shales.[1] A short distance above the base of these shales in the western folded portion of the plateau, a local quartzite, from three to six feet in thickness, ripple-marked, sun-cracked and sometimes gritty, is a member of the gently-folded N.–S. anticlines and synclines.[2] The Fort of Bhainsrorgarh is built on a bluff of Rewah shales overlooking the Chambal river ; here the shales are quite horizontal and are traversed by widely-spaced, perfectly straight master-joints, so persistent in length and depth that the face of the bluff, defined thereby, has the appearance of having been artificially dressed. It is doubtful whether the Panna Shales are represented in Bhopal ; the Lower Rewah Sandstone, the Jhiri Shales and the Upper Rewah Sandstone, however, are all present in that state.

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[1] J. B. Auden. *Mem.*, LXII, 216, 220, 223 (1933).

The Upper Rewah Sandstone is not unlike the Kaimur, but is generally less hard and quartzitic, more impure, and somewhat coarser in grain ; furthermore, it is usually darker in colour, more prone to iron-staining, characterised by more frequent intercalations of shale, and more liable to break along joints into large cubical blocks. It usually presents a mixture of massive strata and current-bedded flags ; nodules of brown ironstone, weathered out from the sandstone, are very frequent on the dip-slopes. The full thickness of this sandstone in the Rewah State, where not denuded, is nearly 500 feet. Westwards, along the Narbada valley, it increases to not less than 1,000 feet at Katangi, and to close on 6,000 feet at Hoshangabad ; in the Dhar Forest area, its thickness is said to be nearer 10,000 feet, but it is uncertain whether this section belongs entirely to the Upper Rewah. In Bhopal and the Dhar Forest, the Upper Rewah Sandstone is purplish, quartzitic, frequently ripple-marked and conglomeratic, the pebbles which are of no great size consisting of metamorphic and other rocks ; the sandstone here rests quite unconformably upon the Bijawars and contains fragments of the latter in its conglomerate. In eastern Rajputana, though only about 130 feet thick the Upper Rewah Sandstone forms a prominent landmark above the shales, and is much indurated, approaching nearer to the consistency of quartzite than any other of the Upper Vindhyan stages.[3] It is here fine-grained, compact, white or pale grey, sparingly stained with purple near its joints and occurring in beds of uniform and medium thickness, with intercalated zones of thin-bedded, flaggy strata ; the whole stage is regularly jointed and shows great regularity of type, the top of the scarp consisting of a very distinct, massive, white quartzite with a marked tendency to weather along its joints into very large sub-spherical blocks. In Bundi the rock, usually of a yellow colour, varies very greatly in extent and thickness. It is not exposed southwest of Bundi city but the Fort to the north of the latter is built upon a large mass of it. Its base is here very conglomeratic, pebbles of quartz and small felspars lying in a fine grained, siliceous matrix ; definite limestones come in and at the junction with the Jhiri Shales there is usually some ferruginous ochre and occasionally kaolin.

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[1] A. L. Coulson. *Rec.*, LX, 168 (1927).
[2] A. M. Heron. *Mem.*, LXVIII, 98 (1936).
[3] A. M. Heron. *Mem.*, XLV, 165 (1917).

The dip in Bundi may be as low as 10° or 15°, but in places the folding has been sharp and the beds are highly disturbed ; the maximum thickness is about 300 feet. The rock, being flaggy, is used locally in Bundi for building purposes. Further southwest, near Bhainsrorgarh, the stage is much reduced in thickness, in some places to three feet only, and is interbedded with shales ; further in this direction it thickens again considerably and includes shales. In the Parsoli-Bichor area, southwest of Mandalgarh, gritty and finely conglomeratic bands form part of the sequence and near the top are highly ferruginous, passing up into the Ganurgarh Shales.

Diamonds in the Vindhyans.—Diamonds occur in the main Vindhyan basin. Here, as in the Kurnool district of Madras, the great majority of the diggings are alluvial, but the most important workings and those upon which most labour is spent are in a conglomerate at the local base of the Rewah, below what are thought to be the Jhiri Shales. Notwithstanding the wide range of this conglomerate stage, it is known to be productive only within a small area of the Panna State, on the borders of the Bundelkhand Granite. This conglomerate comprises an arenaceous matrix with vein-quartz pebbles derived from the granite area, jasper pebbles from the Bijawar series, and others—especially those of a green vitreous quartzite—from the Lower Vindhyan ; fragments of heavy minerals such as galena are also present. The diamonds occur as pebbles among the others.

Near the town of Panna, the principal diamantiferous conglomerate—locally known as *mudda*—rests directly upon the uppermost surface of the Kaimur Sandstone, and, though often discontinuous, is found over a large area ; its thickness seldom exceeds two feet. A more friable conglomerate with a shaly matrix, also diamond-bearing, sometimes overlies the more indurated sandy one.[1] East of Panna, in the neighbourhood of Itwa, the diamond-bearing conglomerate is separated from the Kaimur Sandstone by 20-25 feet of shale and limestone, while a subsidiary band of sandstone, some 20 feet thick, overlies the conglomerate and underlies the Jhiri Shales. Four miles further east is another diamondiferous conglomerate at the upper sufrace of this subsidiary sandstone, between it and the Jhiri Shales. In some of the workings, as for instance those at Sakeria, diamonds have been obtained from a horizon which is believed to be higher in the sequence and to occur at the base of the Bhander (Ganurgarh) Shales, overlying the Upper Rewah Sandstone. Whatever its precise position may be, the large pebbles of the gravels derived from this higher conglomerate consist exclusively of vein-quartz. The point is interesting in that it confirms the conclusion that the diamonds were originally derived from the Bundelkhand Granite area in which the vein-quartz occurs. The absence in this particular conglomerate of the jasper pebbles of the Bijawar rocks and the quartzite pebbles of the Lower Vindhyans, both of which types are abundant in the lower conglomerate, shows that the material of the upper conglomerate is neither a redistributed product of the lower one, nor one derived from the denudation of either of the above formations. The quartz pebbles derived from the granitic area must, therefore, be looked upon as the essential associates of the diamonds, and the original home of the gem must be—not, as was first suggested, the greenish quartzite of Lower Vindhyan age—but one of the rocks of the granitic region, either the granite itself, or its quartz reefs, or more probably the basic dykes which traverse it. As we have seen, the diamonds of Madras occur in conglomerates of presumed Lower Vindhyan age in close proximity to a crystalline gneissic or granitic area traversed by innumerable basic dykes—in this case, of Cuddapah (Cheyair) age.

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[1] E. Vredenburg, *Rec.*, XXXIII, 89 (1906).

The discovery of diamonds in the Panna State is of more recent date than that made in southern India. The Panna gems belong to the hexakisoctahedral form, with curved faces ; the majority are unbroken and remarkably perfect. Measurements made by S. Ramaseshan prove that the curvature of the crystal faces is greater in the case of smaller diamonds ; that the curvature is in no way the result of erosion but is an intrinsic property of the diamond is indicated by the fact that each face is practically a spherical triangle. These facts support the conclusion of Sir C. V. Raman that such curvature is due to interfacial tension between the drop of liquid carbon before solidification and the parent magma, and not a result of corrosion effected by a solvent or of mechanical erosion. The colour is either a brilliant white, or a more beautiful blue white which is unknown among South African specimens. The stones are obtained from cylindrical pits up to 60 feet in depth and sometimes connected by galleries. To extract the gems, the conglomerate is rendered friable by repeated surface heating.

Bhander series.—As a result of the very flat basin-like nature of the main Vindhyan area, the youngest series, the Bhander (Bundair ; Bhanrer), covers a larger exposed surface than the others ; its outcrop includes a very large tract from Saugor to beyond Rewah, spreading over a wide extent of country southwest of Agra. A considerable portion of the Trap area north of the Narbada and east of Nimach (Neemach) is known to be underlain by beds of the Bhander series ; this is proved by the occurrence of inliers far away from the boundary of the main outcrop.

Of the Lower Bhander, the Ganurgarh (Gunoorgurh) Shales at the bottom and the Sirbu (Sirboo) Shales at the top are of the usual Vindhyan type ; the latter are frequently aluminous. Rain-drop pitting, as well as ripple-marking, has been observed in these shales. In the Ganurgarh Shales of Mewar, 50-100 feet thick ripple-marking is abundant and sun-cracks are often to be seen ; here the beds are characterised by a somewhat conspicuous red colour, except in the Parsoli-Bichor syncline where they are light brown. Near Bhainsrorgarh, the Ganurgarh Shales are surprisingly insignificant and nondescript ; here they are grey in colour, sandy, rather hard and splintery, with a few layers of yellowish brown limestone.[1] In the type area of Baghelkhand, the Ganurgarh Shales are 400 feet thick, but in Bundi, where they form a very constant member of the Bhander series, they attain an average of 600 feet.[2] In the latter State, they usually possess a cross-jointed slaty cleavage and are more ferruginous than the average Vindhyan shale ; intercalated with them are thin-bedded, pinkish limestones, sandstones and quartzites. In eastern Rajputana, the bright red and yellow Ganurgarh Shales, 150-200 feet thick, resting on the Upper Rewah Sandstone, pass up into the Bhander Limestone.

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[1] A. M. Heron. *Mem.*, LXVIII, 103 (1936).

[2] A. L. Coulson. *Rec.*, LX, 173 (1927).

The Bhander Limestone is the most variable rock of the series, but is one of the most constant of the Vindhyan stages and for that reason an important marker horizon. Sometimes there are as much as 260 feet of firm stone ; elsewhere there is much less, the carbonate of lime being disseminated amongst the calcareous shales associated with the limestone and partly taking its place. The limestone is generally earthy and compact, of grey, yellow or reddish tints. Heron remarks that it is not unlike the Nimbahera Limestone, though its peculiar concretionary variety, is not to be matched in the older rock. Like the Nimbahera Limestone, it weathers into smooth grey slabs with distinct and moderately thick bedding, often varied with yellow and brown argillaceous bands. In Mewar, where it is 250-300 feet thick the limestone becomes sandy at the top where it passes up into the Sirbu Shales ; in eastern Rajputana (Karauli), its thickness is 260 feet. In Bundi State, this easily recognisable limestone is from 200 to 300 feet thick, thin-bedded, typically grey-blue but sometimes pink or purple in colour, cherty, and with very little crystallisation ; it is used for building purposes and for lime-burning in the Damoh area, and for lime and cement manufacture at Lakheri where it contains more than 16 per cent. of silica.[1] The curious markings abundant on the weathered surfaces of certain of its beds in Bundi are, according to Dr. Heron, concretionary and not organic. In eastern Rajputana, this stage some 260 feet thick, is of much the same character and passes up into overlying sandstones and shales through fine, yellow, nodular, siliceous beds.

The Lower Bhander Sandstone is one of the most inconstant divisions of the Upper Vindhyan, and is frequently absent altogether—as it appears to be in Bundi. In eastern Rajputana, it cannot be separated from the Sirbu Shales.

In their type area of Sirbu Hill in Rewah, the Sirbu Shales vary from 300 to 800 feet in thickness. In eastern Rajputana (Karauli), they are 500-600 feet thick but thin out markedly when followed southwestwards through Bundi to Mewar, where they form a thin but persistent band along the Bhander scarp, 100 and 150 feet thick, respectively. All the cliffs rising from the low ravine country near the Chambal and known as the *kherar* in eastern Rajputana are composed of these shales, dark red and olive in colour, more sandy and thicker-bedded than the Panna or Jhiri shales of the neighbourhood, and containing several subordinate sandstones similar in character to the Upper Bhander. In Bundi and southeastern Mewar, where the Lower Bhander Sandstone is unrepresented, the Sirbu Shales, locally known as the Samria Shales, rest directly upon the Bhander Limestone. Heron describes them as grey, drab, olive, and dark red-brown in colour, hard, and splintery, non-fissile, and rather thick-bedded for shales, with numerous thin beds of fine-grained sandstone which project on weathering. At their base are passage intercalations with the underlying limestone through a vertical distance of ten or fifteen feet ; near the base is a band of massive pink sandstone. At the top, these beds pass into grey and pinkish purple, ripple-marked sandstones, blotched with brown. In Mewar the upper portion of the Sirbu Shales is in most places concealed by débris from the overlying Upper Bhander Sandstone. In Bundi, this stage probably includes some fissile and ferruginous shales described by Dr. Coulson as capped in places by intercalations of grits, sandstones and quartzites, the grits containing abundant angular and rounded fragments of quartz.

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[1] Abstr. Joint Meeting, *Ind. Acad. Sci., & Nat., Acad. Sci.*, Hyderabad, Dec. 1943, p. 12, "*Current Science*," Vol. II, p. 261 (1942).

The Upper Bhander Sandstone differs considerably from the Rewah and Kaimur sandstones and is less metamorphosed. Typically, it is softer, very fine in grain, often shaly, and generally distinguishable by its characteristic colour of deep red with white specks, or paler tints with or without red streaks. There is an immense profusion of ripple-marking, while sun-cracks and water-channelling are not infrequent ; rain-pitting, however, does not appear to have been observed. The individual beds are usually thinner than those of the older sandstones. From six to eighteen inches is a common thickness for the flags but many rise to three or four feet ; more massive beds do occur, as witness the great monoliths cut from the quarries at Rupbas (Rupas) near Bharatpur. Fine flags are quarried at Damoh. The Upper Bhander Sandstone is perhaps the most important building-stone of northern India and has in the past been the predominant material used in the historic buildings of this part of the Peninsula, especially in those of Agra and Delhi. In the type area its thickness varies from 200 to 3,000 feet.

In eastern Rajputana the Upper Bhander Sandstone stage is from 500 to 600 feet thick, and covers the surface of the plateau, a part of which—locally known as the *dang*—has been separated off from the main portion by the Chambal river flowing from southwest to northeast. From the bold scarp overlooking the river there is a very gentle decline of the *dang* surface northwestwards towards Karauli city. Contrary to its usual habit, the Upper Bhander Sandstone is here often full of small quartz pebbles, scattered and in strings and layers, an indication perhaps of the proximity of the original limit of deposition.[1] In Bundi, it is the most strongly developed stage of the Upper Vindhyan and attains a total thickness of about 2,600 feet ; it is here characterised by rolling dips up to 25°, but along the northern part of the outcrop it is much disturbed, with dips of 70° and 80°. The lower beds in Bundi are usually fine-grained, red and compact, and are succeeded by a great thickness of white quartzite with a coarse grit at its base which has been used for glass-making ; the weathered surface of the quartzite has a vesicular appearance due to the removal of ferruginous cementing material.

In Mewar, along the northwestern edge of the main plateau, the Upper Bhander Sandstone stage, over 400 feet thick, is described by Dr. Heron as consisting of a basal five feet of pinkish and grey sandstone blotched with brown, followed by red-brown sandstones. The latter, which form the bulk of the stage, occur in thick beds of freestone up to ten feet thick, fine-grained, ripple-marked and current-bedded. These are typical Upper Bhander sandstones except that they lack the fawn and cream-coloured spots and splashes which those sandstones often, but not invariably, exhibit. In the semicircular waterfall at the head of the Mandal cañon, about 40 feet of these massive beds are exposed, overlying 150 feet of Sirbu Shales. These are the sandstones which have been used so extensively in the past ; the temples and gateway of Mandal, constructed of this stone, are said to date back as far as the tenth or eleventh century. In places this useful freestone is replaced by a quartzitic sandstone which, though not so easily dressed, has a quadrangular jointing and has been utilized in local buildings. In the centre of the Parsoli-Bichor syncline, the Upper Bhander Sandstone, here almost a quartzite, has a general resemblance to the Kaimur and the Rewah Sandstones, though darker. Towards the top of the stage in Mewar occur intercalations of reddish shale.[1]

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[1] A. M. Heron. *Mem.*, XLV, 168 (1917).

Bhopal Area.—References have been made above to the Bhopal outcrop of Vindhyans, which is largely surrounded by Deccan Trap basalts, resting horizontally upon the older folded rocks and unaffected by a fault which traverses the latter near Bari. In this Vindhyan sequence, the shale bands intervening between the sandstones are only poorly developed. Neither the basal member of the Upper Vindhyan nor the floor rock on which the beds lie is disclosed. This area includes :—exposures of the Bijaigarh Shales, the lowest stage exposed ; the Upper Kaimur Sandstone with the conglomerate at its base ; the Lower Rewah Sandstone ; the Jhiri Shales (one small outcrop only) ; the Upper Rewah Sandstone ; the Ganurgarh Shales, occasionally at the base of the scarps ; the Lower Bhander Sandstone (with a subsidiary band of shales known as the Sanchi Shales), forming rolling hills and ridges ; the Sirbu Shales, occasionally at the base of scarps ; and the Upper Bhander Sandstone, occupying wide plateaux or occurring as hilly inliers among the Deccan Trap. The rocks lie in a gentle N. W.-S. E. synclinal axis, with dips up to 12°, east of Bhopal town.

From the Upper Vindhyan outcrop of Bhopal and the Hoshangabad district, a long thin ridge of these rocks extends for about 22 miles to just beyond Deori. Further east, a stretch of the Narbada alluvium and the Deccan Trap of not more than 15 miles separates it from the Vindhyan outcrop of the Bhander and Kaimur ranges. This ridge, never more than two miles wide, has a northerly dip of 10°-15°. In the west, Lower Bhander Sandstone, Ganurgarh Shales, Upper Rewah Sandstone, Jhiri Shales and Lower Rewah Sandstone have been identified by Mr. H. Walker, while to the east, the Bhander Sandstone and Ganurgarh Shales lie buried beneath the Deccan Trap, and the Kaimur sandstone and conglomerate appear from under the alluvium. In the neighbouring Deccan Trap occur several inliers of the Upper Vindhyan. As we have already seen, the Lower Vindhyan shales also make their appearance from beneath the alluvium at the Deori gorge.

Dhar Forest area.—West of Satwas, on or near the Narbada river, partly in the Nimar district of the Central Provinces and partly in Indore and Dhar States, an outcrop of sandstones, shales and conglomerates has been assigned to the Vindhyan system, the western portion, according to Vredenburg, including perhaps some beds of the Lower division.[2] Allusions to parts of the Dhar Forest Vindhyan succession have already been made. For 20 miles or so these Vindhyan beds are faulted against the Bijawars along an E.-W. line marked by rich hæmatite breccia.[3] Elsewhere the Vindhyans, dipping at moderate angles, generally towards the west, rest either upon the gneiss or upon the upturned denuded edges of the ancient schists. The predominant rock is one intermediate between a sandstone and a quartzite, of a deep red or purplish colour. The bedding is well-marked, the separate beds are of small thickness generally, and the rock is occasionally flaggy. Conglomeratic bands are not rare and include rolled fragments of the Bijawars. This quartzite or sandstone, with its pebble beds, belongs to the Rewah series. Elsewhere, the sequence includes softer and more shaly beds, grey or greenish in colour, which represent, in part at least, the Bhanders. The total thickness of the Vindhyans in this area is estimated at scarcely less than 10,000 feet.

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[1] These have been mistaken for the (Sirbu) Samria Shale; see A. M. Heron. *Mem.* LXVIII, 110 (1936).

[2] *Rec.*, XXXVII, 50 (1908).

[3] P. N. Bose. *Mem.*, XXI, 15 (1884). *Gen., Rep.*, 1902-3, 14.

Bagh and Jobat.—Further west are two additional very small exposures, one at Balwari to the east of Bagh in Gwalior, and the other at Jobat to the west of Bagh.

Topography of the Upper Vindhyans.—The reciprocal variations in the distribution of the coarser and finer Upper Vindhyan deposits have a distinct relation to their position with reference to the border of the area, the shales being in force towards the middle of the basin, and being replaced by sandstones near the margin ; this distribution shows, as other evidence has already shown, that this border is approximately an original limit, and that the actual basin corresponds fairly closely with the basin of deposition. A formation so constituted and for the most part so little affected by disturbance as the Upper Vindhyan can result in but one form of surface. It, accordingly, presents a threefold plateau, each step comprising one of the main groups, with minor plateaux, terraces or ledges corresponding to the various sub-groups. The thick sandstones form vertical scarps over a talus of the underlying shales. There is, moreover, a basin-shaped lie of the beds, to a great extent original, whereby the surfaces are rendered more or less concave, and the edges of the successive scarps of sandstone rise scarcely higher than the succeeding outer one. From this it follows that the uppermost subdivision occupies by far the larger part of the Vindhyan area. On account of the softer nature of the rock, the scarp of the Upper Bhander Sandstone is less bold than the others. The middle step of the plateau, the edge of which is determined by the Upper Rewah Sandstone, is chiefly occupied by the Ganurgarh Shales ; the sandstone, wherever it occurs in eastern Rajputana, forms a prominent landmark. The outermost step, produced by the Kaimur Sandstone, possesses curious and unique features. Rising to a height varying from 500 to 1,000 feet above the low ground to the south, it stretches for over 200 miles, forming an almost unbroken northern boundary to the strike valley of the Son river just below. The line of the scarp is nearly straight, the only indentation being that near Bijaigarh. The boldness of the precipices is due to the massiveness of the rock. This scarp forms the water parting between the Son and the Ganges, practically all the drainage of the Kaimur plateau flowing northwards to the Ganges. The Son, consequently, in this part of its course, receives no tributaries of any size from the north, but many from the south, some of them draining country a hundred miles distant. As a result of the northerly predominance of the drainage, the northern scarp of the Kaimur plateau is deeply indented. A similar scarp of Kaimur rocks, nearly in a line with the Kaimur scarp and possessing precisely similar features, forms an edge to the Bhander plateau further west for over a hundred miles, and the northern boundary for forty miles or so of the upper Narbada and one of its tributaries. The less altered or unaltered condition of the

Bhanders would seem to indicate that they have not been subjected to the great superincumbent pressure which has more or less affected the lower groups.

TRANS-ARAVALLI VINDHYAN BASIN.

The Vindhyan beds so far described were all deposited on the southeastern side of the great Aravalli chain. On the northwestern flank occur numerous, isolated, and scattered outcrops of rocks which in all probability belong to some part of the Vindhyan period ; these *inselberge*, some of them several square miles in area, are gradually becoming " drowned " in the sand of the Rajputana plain or desert. Assuming the correlation to be correct, the minimum distance between the Vindhyan outcrops on both sides of the range is about 90 miles, a distance occupied by the entire breadth of the synclinorium of Delhi sediments flanked on each side by outcrops of Aravalli rocks and pre-Aravalli gneisses, and a wide spread of thick alluvium northwest of the range.

These trans-Aravalli Vindhyan rocks—for they can scarcely be anything else so far as their age is concerned—comprise both igneous and sedimentary members. The former, under the name of Malani, will be described first.

I. MALANI GRANITE AND VOLCANIC SUITE.

Geological position.—The term "Malani" was first given to a series of rhyolitic rocks in western Rajputana, particularly in the Malani district of Marwar (Jodhpur). With their plutonic and hypabyssal representatives, these rocks have been found to occupy a position of importance intermediate in age between the Delhi and Upper Vindhyan formations. The lower boundary of the Malani rhyolites in Marwar is seen in one section only, near Miniari, some thirty-six miles north of the town of Erinpura. Here the lavas are bent in the form of an arch over steeply-dipping reddish slates or shales, which are on the line of strike of micaceous schists in the plain to the east, referred by La Touche to the Aravalli system.[1] The dip of the two formations is different and the evidence of unconformability is complete. On the west, at the base of the anticlinal scarp, a band of conglomerate, some 20 feet thick, is interposed between the lavas and the slates, resting on the upturned edges of the latter ; the boulders and pebbles in this conglomerate are frequently well rolled and consist of quartzose grit, quartz, schist and slate, evidently derived from the underlying slaty formation. Elsewhere, although actual junctions are absent, nearly vertical slates are seen within a few hundred yards of outcrops of the Malani lava sheets which are quite unconformable both in dip and strike to the older rocks.

With regard to the upper boundary of the Malani lavas, a considerable period of time seems to have elapsed before sandstones of presumed Vindhyan age were deposited upon them. Where the two formations occur together, although both are in such places horizontal, there is clear evidence that the lavas had been subjected to an appreciable period of erosion before the deposition of the sandstones. In the numerous sections of the junction exposed in the scarps north of the city of Jodhpur, the Vindhyan sandstones, which are frequently current-bedded, ripple-marked and pebbly, and more of Bhander than of Kaimur type,[2] are seen to rest upon a very uneven floor of the lavas. As La Touche remarks "this in itself would not be evidence of unconformability, for the surface of the lava flows was probably originally irregular, as is usual with such viscous lavas as these, but the sandstones can sometimes be seen banked up against denuded and scarped edges of the flows". The upper portion of the lava flows, where the latter are exposed beneath these scarps of sandstone, is usually found to be weathered to a considerable depth, the product being a soft, rotten rock ; where the lavas have not been protected by the sandstone, this weathering of the surface is not observable. The weathering, therefore, according to La Touche, must have taken place before the deposition of the sandstone and, if the effects of atmospheric agencies at the present time are in any way a measure of what they were in the past, it must have taken a considerable period of time to produce the results noted on such resistant rocks. At the base of the sandstones there is frequently a layer of varying thickness in which large blocks of the lava are embedded in silt and grit. These are not water-worn boulders transported from a distance, but are always of the same variety of lava as that composing the sheet immediately underlying them ; they have evidently been weathered out *in situ*, and then quietly buried in silt. Lastly, in a few places, patches of true conglomerate, including water-worn and well-rolled pebbles and boulders of the lavas, transported from a distance, are found occupying hollows in the uneven surface of the lava flows, and underlying the sandstones ; these conglomerates are associated with beds of fine red and green shale, also of local occurrence.[1]

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[1] *Mem.*, XXXV, 20 (1902).

[2] J.B. Auden. *Mem.*, LXII, 244 (1933).

If we try to match these acid lavas of the Malani suite in neighbouring areas, the nearest equivalents seem to be the Porcellanites of the Lower Vindhyan in the Son Valley, and it is with these that the Malanis are provisionally correlated.[2]

Analyses.—The following are analyses of some of the types[3] :—

—	Potash-granite, Ban, Sirohi.	Quartz-felspar porphyry, north-west of Danta, Sirohi.	Banded rhyolite, near Alpa, Sirohi.	Dellenite, north-west of Sindret, Sirohi.
	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2 . . .	75·46	69·98	74·80	70·62
TiO_2	0·52	0·81	trace	0·78
Al_2O_3	11·11	12·92	13·05	13·24
Fe_2O_3 . . .	0·11	0·31	0·35	2·37
FeO	2·24	3·71	1·17	1·71
MnO	0·09	0·10	0·04	trace
MgO	0·18	0·80	0·11	0·85
CaO	1·16	1·16	0·94	0·98
Na_2O	2·75	2·68	4·16	2·71
K_2O	5·64	5·62	4·58	5·28
H_2O(—105°C.) . . .	0·28	0·19	0·21	0·31
H_2O(+105°C.) . . .	0·51	1·56	0·83	1·38
CO_2	..	0·13	trace	0·12
P_2O_5	trace	0·07	..	0·11
	100·05	100·04	100·24	100·66
Specific Gravity . .	2·647	2·637	2·617	2·642

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[1] T. H. D. La Touche. *Mem.*, XXXV, 26-27 (1902)

[2] J. B. Auden. *Mem.*, LXII, 244 (1933).

[3] F. Racult. *Mem.*, LXIII, 117 (1933).

Mutual relationships.—The Malani series of acid plutonic, hypabyssal and eruptive rocks, with their sedimentary accompaniments, is one of not very wide extent, though recognised at various points within an appreciable area. Much of the Malani Granite was at first called the "Idar Granite". In Mewar, Danta, Palanpur and Baroda States, the Malani Granite and its modifications are not found. The rhyolites have in some places been clearly invaded by their own granite, which does not penetrate the overlying sandstones believed to belong to the Upper Vindhyan, and the general order of formation seems to have been: (1) Malani rhyolites, tuffs and sedimentaries; (2) Granite; (3) Porphyries; (4) Quartz veins. There were, however, local deviations from this order and it will be convenient to describe the granite and its hypabyssal derivatives first.

(a) MALANI GRANITE AND ITS HYPABYSSAL EQUIVALENTS.

SIROHI STATE.

Three principal groups.—Of the three principal groups of Malani Granite outcrops in Sirohi State, the most northerly one at Ban is interesting in that it is associated with rhyolites and separated therefrom by a hypabyssal facies in the form of granite porphyry; it is surrounded mostly by desert sand and alluvium but is for a short distance in intrusive contact with Aravalli shales and slates. The Isri outcrops intrude the Aravallis and the Erinpura Granite more or less along the contact between them. In the Nandwar Hill and Sunda Hills group of outcrops, in the border country of Sirohi and Marwar, the Erinpura Granite is clearly intruded by the Malani Granite in its various modifications; while the older granite is in places highly crushed and altered, and is intruded by its own pegmatite and by basic dykes, the Malani Granite, here porphyritic, is free from both these forms of intrusion.

Composition.—In the typical facies of the Malani Granite in Sirohi, biotite is predominant over hornblende, as it is in the Jalor outcrops of Marwar. Fluorite is an occasional but rare accessory and tourmaline is present in some cases. Muscovite is a rare constituent of the Isri outcrops, the chief mineralogical characteristic of which is the granophyric texture of the greater part of the groundmass. Some specimens from Nandwar Hill show a considerable quantity of plagioclase. The number of modifications of the granite on Nandwar Hill is responsible for Coulson's suggestion that there has been an intermixing of two magmas of the same age.[1]

In Sirohi, there is a perfect gradation from normal granite, with or without a coarse grained eutectic intergrowth of quartz and orthoclase, through porphyritic granites with the same but finer-grained groundmass, to quartz porphyries, quartz-felspar porphyries, felspar porphyries, granite porphyries, etc., with a still finer groundmass. Some of the porphyritic types are marginal facies of the ordinary granite and show brecciation; in some cases they possess a certain similarity to rhyolitic types. From the evidence of slickensiding, it would appear that the intrusion of some of the dykes of porphyritic granite was accompanied or followed by faulting.

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[1] *Mem.*, LXIII, 110 (1933).

Porphyry dykes.—A well-developed swarm of felspar porphyry dykes penetrating the Erinpura Granite near Danta[1] and Sindret, trend almost at right angles to the general strike of the country ; these dykes are slightly younger than the quartz porphyries and rhyolites. This is not the only locality in which such a trend is observable, but in some cases the strike of the dykes and that of the country rock are more or less parallel. In the porphyries from Sindret and Danta, hornblende is the usual ferromagnesian mineral. Most of the felspar phenocrysts are orthoclase, with varying amounts of perthitic and microperthitic intergrowths of acidic plagioclase which is probably albite ; phenocrysts of andesine, however, do occur.

The dykes are intrusive towards the Erinpura Granite and are associated with rhyolites and quartz-trachyandesites (" dellenites " and " toscanites "), all of Malani age. The felspar porphyries are considered by Coulson to be the hypabyssal equivalents of the quartz-trachyandesites. The edges of the dykes show the effects of chilling.

In certain of the felspar porphyries, the large orthoclase phenocrysts are frequently surrounded by a rim of what appears to be a very fine-grained myrmekitic intergrowth of quartz and orthoclase, both minerals extinguishing with the phenocryst. There seems to have been partial solution of the orthoclase phenocryst around its edges, silica in the form of quartz crystallising out in the place of the dissolved orthoclase. The phenomenon is akin to the " quartz-mosaics" in the rhyolites of western Rajputana (*vide infra*).

Quartz veins.—One of the most characteristic differences between the Malani and Erinpura granites is the large amount of pegmatite which accompanied the latter and the conspicuous freedom from such acidic differentiates in the case of the younger rock ; this is attributed to the greater size and deeper seating of the Erinpura magma reservoir. The place of the pegmatite is taken by quartz veins, a few inches only in thickness, but in Sirohi it is extremely exceptional for these veins to approach in size the reef-quartz veins which accompany the Erinpura Granite.

MARWAR STATE.

Two types.—In Marwar (Jodhpur) the Malani Granite is described as generally coarse in grain, but not nearly so coarse as the Erinpura Granite. There are two lithological varieties, one—the Siwana type—containing quartz in abundance, pink or white felspar, and hornblende, but no mica, and the other—the Jalor type—containing the same minerals with mica in addition. The granite is practically contemporaneous with the rhyolites, but where the two are in contact, the granite, in the great majority of cases, is intrusive towards the lavas.

Siwana type.—The Siwana type is found in the interior of the volcanic area and forms the greater part of the large mass of the Saora range, rising over 3,000 feet above the sea ; several other bosses occur in the neighbourhood. The granite magma has forced up and pushed aside the lavas, and has projected into them narrow ramifying veins consisting frequently of a coarse pegmatite containing well-shaped crystals of hornblende an inch or more in length. Elsewhere, where the rhyolites strike towards the granite, the latter appears to have re-melted, absorbed and replaced the lavas.[1] The joint-planes of the rhyolites in the neighbourhood of the granite are often coated with a thin glaze of granite, the latter having evidently been forced in among the rhyolites under great pressure and in a very fluid state. The granite has also torn off large blocks of the rhyolite and included them. The rhyolite near the contact with the granite, as well as that in the included blocks, has been considerably altered and is full of small nests of hornblende. Sometimes the granite abuts vertically against the rhyolite, sending into it the usual plexus of veins. The granite of Saora Hill is frequently traversed by broad veins of a cryptogranite or eurite of the same composition; when these veins contain large porphyritic crystals of pink felspar, the material resembles to some extent the rhyolite but is distinguishable therefrom by its lighter colour and its less glassy texture.

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[1] Not to be confused with the State and town of that name further south, nor with another small town in Jaipur.

The hornblende of the Siwana granite is usually interstitial but occurs occasionally in idiomorphic crystals, especially in the veins and dykes, protruding from the main mass into the surrounding rhyolites. The felspar and quartz frequently form a micropegmatitic intergrowth. There is a singular dearth of accessory minerals, even magnetite being rare.

The Siwana granite bosses lie along a more or less continuous ring, 19 miles across from west to east, and 16 miles from north to south. Whether this almost circular plan has any connection with the roots of a volcano is not known, for the disposition of the flows and ash beds, which might have afforded some indication, has been disturbed by subsequent earth movement.[2] The Siwana type of granite forms several hills in the Barmer area further west, where it was also intrusive into the lava sheets in contact with it; at the same time, the granite is traversed by dykes of a rock indistinguishable from the lavas, and injected after the consolidation of the granite.

Jalor type.—The Jalor type of granite is confined to the eastern edge of the volcanic area, where its large bosses are either surrounded by highly inclined Aravalli schists, or in a few cases are in contact with the lavas, into which the granite is seen to be intrusive.[3] In this granite, the predominant ferromagnesian is biotite, there is a moderate proportion of plagioclase in addition to orthoclase, and muscovite sometimes accompanies the biotite. Dark rounded patches in the granite, up to six inches or a foot across, are to be seen in places; some of these appear to be included fragments of schist, others are probably of the nature of cognate xenoliths and contain the same ingredients as the granite. The granite of the Jalor area not only sends off veins into the surrounding lavas but also includes blocks thereof. Like the Siwana rock also, it is in places traversed by thick veins of fine-grained cryptogranite or eurite. An example of a large dyke-shaped mass of rhyolite split off and embedded in the granite is seen some sixteen miles northeast of Jalor; its edges have been partially re-melted, for a fluidal structure following the irregularities of the boundary has been developed in it, and its colour has been bleached for about half-an-inch from the junction. In the Barmer area, we find the same dykes of eurite, the darker coloured ones being indistinguishable in appearance from the rhyolites.

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[1] A. L. Coulson. *Mem.*, LXIII, 14, 140 (1933).

[2] *Gen. Rep.*, 1897-8, p. 35.

[3] T. H. D. La Touche. *Mem.*, XXXV, 24-25 (1902).

Topaz-granite and wolfram-bearing veins of Rewat.—The topaz-bearing granite of Rewat, near Degana railway junction, is probably the Malani rock, and is intruded into the Aravalli phyllites.[1] Penetrating the granite are many steeply-hading veins, from six to eighteen inches wide and with a N.E.-S.W. strike, of quartz and biotite, disposed in bands parallel to the vein walls, the biotite usually but not invariably next to the walls. Developed indiscriminately in both quartz and biotite, but chiefly in the former, are bladed and tabular crystals of wolfram. Fluorite is common in the veins and the phosphates, triplite and libethenite, have been detected. During the four years, 1916-1919, as an effect of the War, some 40 tons of wolfram were obtained annually from this area which is still worked sporadically.[2]

BIKANER.

Isolated tors.—In the extreme southeast corner of Bikaner, near Lodsar and Taonra, two villages on the other side of the Marwar frontier, is a small tor of fine-grained, non-porphyritic and unfoliated granite, probably of Malani age. A similar but larger tor, also in Bikaner, three miles east of Khuti, is probably of the same rock.[3]

HISSAR DISTRICT, PUNJAB.

Tusham granite.—The granite which crops out on the south, southwest and west of Tusham Hill, (Tosham) in the Hissar district, some 80 miles W.N.W. of Delhi, is associated with effusives having undoubted resemblances to the Malani rhyolites, and probably belongs to the Malani suite. It is a coarse-grained rock extremely rich in tourmaline and muscovite. The quartz and felspar are much intergrown, but some of the smaller crystals of the former exhibit hexagonal outlines. In some respects, the rock is a transitional stage between a normal granite and a quartz porphyry. Another specimen from a different part of the hill contains a black mica in considerable quantity in place of muscovite. The northern portion of the hill is traversed by granite veins ranging from a few inches to a few feet in thickness ; some of them cut across the strike of the old sedimentary rocks.

Porphyritic varieties.—In some of the hills near Tusham is a fine-grained porphyritic granite with quartz, felspar and black mica, the felspar consisting of plagioclase, orthoclase and microcline.[4]

In the Khanak hills, three miles northwest of Tusham, is another fine-grained porphyritic granite with triclinic felspar and orthoclase in about equal proportions but no microcline. In addition to the quartz and felspar, there are numerous small garnets, abundant black mica, some apatite, and a considerable quantity of magnetite or ilmenite mostly associated with the dark mica.

On Deosir, an isolated hill southeast of Tusham and four miles southwest of Bhiwani, is a grey, fine-grained granite or porphyry with large phenocrysts of felspar, quartz and dark mica, in a microcrystalline groundmass. Some of the phenocrysts show crystal outlines, others are corroded and contain inclusions of the groundmass. Plagioclase and glassy orthoclase are both present, the other constituents being small garnets, a little tourmaline and numerous dots of an opaque mineral.

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[1] *Gen. Rep., Rec.*, LXVI, 82 (1932).

[2] *Gen. Rep., Rec.*, LXVII, 60 (1933).

[3] *Gen. Rep., Rec.*, LXVI, 133 (1932).

[4] C. A. McMahon. *Gen. Rep., Rec.*, XVII, 111 (1884).

Quartz porphyry dykes.—Two dykes of quartz porphyry traverse the Tusham ridge, the strike of the one being at an angle of 45° with that of the other. The more eastern of the two cuts obliquely across the old bedded rocks at a low angle, and throws out a tongue at right angles to its own direction; in another place it encloses a mass of these old rocks. About a mile or so to the east of Tusham is a small isolated hill of granitoid quartz porphyry.

The quartz porphyry of the main dyke contains large porphyritic crystals of quartz and felspar, some of the latter being an inch in length; the felspar phenocrysts are partly orthoclase and partly plagioclase, and are much altered and kaolinised. The quartz crystals, in which gas and liquid inclusions are abundant, are much corroded, and characteristically contain inclusions of the groundmass; many of them are fringed with a thin border of mica.[1] The pyramidal ends of some of the quartz crystals, nearly perfect in form, stand sharply out from the fractured surface of a hand-specimen. The groundmass varies from microfelsitic to microgranitic and shows a tendency towards spherulitic structure. Some ilmenite is present. In the rock of the tongue which protrudes from the dyke into the adjoining rocks, patches of chlorite and a mineral that looks like pinite occur in the much decomposed felspars, some of which are triclinic; the groundmass is here microfelsitic. The description of the petrological characters of these quartz porphyries is not unlike that of the microgranites from the so-called "trappoids" of the Porcellanite stage of the Son valley Lower Vindhyan.

Relationships.—All these porphyries, granites and "felsites" found in and around Tusham are closely related to one another and to the rhyolites and porphyries of Marwar, and may be referred with some degree of confidence to the Malani suite.

(B) MALANI VOLCANICS.

Distribution.—In Marwar, from east to west, the Malani rhyolites have been recognised in scattered outcrops for a distance of 145 miles, from a little east of the meridian of Jodhpur to the edge of the great Thar desert which effectively conceals any further exposures that may exist in this direction. From near Pokaran in the north, the lavas have been traced southwards to the centre of Sirohi State, a few miles north of the Abu plateau edge—a distance of about 156 miles. The "felsites" in Tusham Hill, however, some 250 miles northeast of the nearest occurrences of the rhyolites north of Jodhpur city, are, as we have just seen, probably referable to the Malani suite, and typical Malani rhyolites have been identified in northern Jaipur and the adjacent Bikaner borders. Between the Tusham exposures and some rhyolites in the Kirana Hills in the Jech Doab,[2] in the Jhang district of the Punjab, a distance of some 275 miles to the northwest, there are no outcrops of rock of any kind, everything being covered by desert sand. The isolation of the Malani exposures makes it impossible to establish any regular sequence among the volcanic suite or to form any estimate of its total thickness.

Salt Range boulder bed.—Boulders of the Malani granites, rhyolites and probably also the tuffs have been identified among the contents of the Upper Carboniferous Talchir Boulder Bed of the Salt Range which is some 40 or 50 miles distant from the Kirana locality.[3]

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[1] C. A. McMahon. *Rec.*, XVII, 107 (1884).

[2] The Jech Doab is the name given to the country lying in the fork made by the Chenab and Jhelum rivers.

[3] C. S. Middlemiss. *Rec.*, XXV, 29 (1892); F. R. Cowper Reed., G. de P. Cotter and H. M. Lahiri. *Rec.*, LXII, 417-20 (1929); A. L. Coulson. *Mem.*, LXIII, 141 (1933).

SIROHI STATE.

Trend of the exposures.—Effusive rocks of the Malani suite are not recorded in Idar State but have been found in four areas in Sirohi, where they all lie along the same line of strike with a slight *echelonnement* in the north. A series of vents or cracks, later than those responsible for the extrusion of the rhyolitic lavas, was filled with material which probably never reached the surface but on cooling gave rise to the porphyritic granites and the various porphyries described above. As a rule, these later intrusions trend N.N.E.—S. S.W., making a small angle with the general direction of the Aravallis and the direction of the rhyolitic vents, but many of them are at right angles to the trend of the majority.

Jharoli-Ban area.—In the Jharoli-Ban area, in the north of the State, rhyolites overlie Aravalli shales and slates and are separated from the Malani Granite of this locality by an outcrop of granite porphyry.[1] The contrast between the smooth, rounded hills of granite and the rugged, jointed hills of rhyolite is striking. An example of the rhyolite shows crystals of quartz, orthoclase and acidic plagioclase, set in a fine-grained, apparently devitrified groundmass, composed of quartz, chalcedony, felspathic material and a little calcite. A little chlorite is present and the felspars show kaolinisation and sericitisation.

The predominant colours of the lavas in the Jharoli-Ban area vary from dark brown to red, a result of the presence of oxide of iron. Corrosion of the felspar phenocrysts is common. Flow structure and banding are also frequent, but perlitic textures are comparatively rare. Inclusions of shale and other Aravalli rocks are often seen, and in one place a black rhyolitic tuff containing fragments of slate, reef-quartz, shale, and other rocks overlies the Malani Granite. The rhyolitic rocks of this area are highly siliceous and in most cases the original glass has become devitrified to an extremely fine-grained siliceous mass. A very agglomeratic facies, west of Jogipura, probably marks the site of a subsidiary pipe or vent where the extrusion of the lava was violent in nature. Near Ora the rhyolites, which are here largely chloritised, are thought to have issued from fissures.

Pamta Hill.—Pamta Hill, to the west of Sindret, is composed chiefly of rhyolites and quartz-trachyandesites ("dellenites" or "toscanites"). The rhyolites, occurring mainly at the southern and northern extremities of the hill, are generally green in colour, and form a strong contrast to the usual reddish tints of the slightly later and more basic quartz-trachyandesites, which they underlie in places. The rhyolites, and also the quartz-trachyandesites when not superjacent to the rhyolites, overlie unconformably the Aravalli beds and their contemporaneous volcanics. Pillow or spheroidal weathering is seen in some of the flows while nodular varieties give rise to hills steeper than usual ; in the latter are many traces of perlitic structure. Some of the rhyolites are vesicular.

The quartz-trachyandesites at the base of Pamta Hill and overlying the Aravalli rocks appear to be partly tuffaceous, some specimens containing abundant angular and eroded fragments of quartz and less frequent orthoclase and plagioclase crystals set in a groundmass of fine-grained silica and palagonitisation products. The normal higher-lying trachyandesites weather angularly to form steep sided hills ; typically they contain phenocrysts of quartz, orthoclase—at times microperthitic

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[1] A. L. Coulson. *Mem.*, LXIII, 129, 131(1933).

—and plagioclase (andesine), all occasionally corroded, set in a devitrified groundmass. The original hornblende has been more or less completely altered to chloritic products and epidotic and zoisitic minerals. The felspars are kaolinised and sericitised, and secondary calcite is common. Iron ore is a frequent accessory; less common are apatite, sphene and zircon. The specific gravity of these rocks varies from 2·60 to 2·71, the average being about 2·66 ; an analysis of a sample will be found on page 534.

Mirpur-Undwaria area.—Further south, in the Mirpur-Undwaria area rhyolites are the sole volcanic rocks found. Relics of spherulitic structure are to be seen in some specimens, and flow structure is common. Some of the horizons are tuffaceous and characterised by frequent fragments of shale.

MARWAR STATE.

General Character.—Most of the Malani flows in Marwar are rhyolites of a highly acid type, varying greatly in colour and texture. They have been described in detail by La Touche.[1] The commonest variety is a reddish brown rock studded with porphyritic crystals of pink felspar and minute blebs of quartz. Sometimes the porphyritic crystals are absent. The hard and extremely siliceous condition of the lavas may be due partly to alteration, but there is clear evidence that they were true volcanic ejectamenta. In them can be observed all the characteristics of glassy lavas, *viz.*, glassy texture, flow-structure, spherulitic structure ranging from microscopic examples up to nodules an inch or more in diameter, and in a few cases perlitic structure—one of the most reliable indications of a true glass ; in some examples the glassy texture has undergone scarcely any alteration. Vesicular or amygdular structure is not often met with but does occur in some of the flows. In many places, the lavas are interstratified with thick beds of tuff, breccia and conglomerate, while intercalations of less acid material in the form of lava or tuff are known. Portions of the sandy plain are covered with a fine angular gravel derived *in situ* from the weathering of the lavas.

Composition.—A reddish brown is the commonest colour of the lavas but many are bright red, blue, green or almost black, and a few are white or light grey. The colour is due in most cases to the presence of oxides of iron, but in the green and yellow varieties to the abundance of hornblende or chloritic minerals. Phenocrysts of quartz and felspar occur in nearly all the lavas but are in a few cases entirely absent. The quartz phenocrysts, which contain characteristic gas, liquid and glass inclusions, in many cases possess perfect hexagonal or octagonal outlines, but more frequently the original shape has been destroyed by corrosion, the groundmass projecting far into the interior of the crystal in fantastic inlets or tongues ; in other cases corrosion has taken place along zones concentric with the outer boundary of the crystal. In some crystals, isolated inclusions of the groundmass, of a more or less hexagonal outline, are seen. Occasionally, there is a growth of secondary quartz surrounding the original phenocryst and in optical continuity therewith. The felspar phenocrysts are either much clouded by dusty matter and zones of inclusions, or are completely converted into kaolin. The majority of them are of orthoclase, many having the glassy appearance of sanidine, but oligoclase has been noted. As a rule, they show no signs of corrosion, but frequently have well-defined crystal outlines. Phenocrysts of hornblende with well-defined outlines occur in a few specimens, and irregular aggregates of hornblende microlites are a little more common. The hornblende is generally associated with much opaque magnetite, and is frequently altered into a light yellow chloritic mineral.

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[1] *Mem.*, XXXV, 19-24 (1902).

The groundmass varies from cryptocrystalline to microgranitic and is never entirely glassy. Most of the microlites are of orthoclase, but occasionally striated twinning can be made out. On the application of polarised light, the quartz of the groundmass in many specimens breaks up into a more or less irregular mosaic of light and dark areas which, when in contact with the quartz phenocrysts, are in optical continuity therewith. La Touche concludes that each of the areas forming the quartz mosaic has been built up round a previously existing granule of quartz, or as a " court " round the larger phenocrysts of quartz, both granules and phenocrysts having been introduced from outside. The size of these areas would depend upon the number and distribution of the granules and phenocrysts, the quartz composing any individual of the mosaic growing outwards until its development was arrested by contact with surrounding individuals. This quartz-mosaic structure is not universal; La Touche is inclined to regard it as having been formed before consolidation,[1] and Fermor suggests that it is a case of devitrification in a lava still hot.[2] Spherulitic structures are of very common occurrence. Sometimes the spherulites are isolated globules scattered about in the body of the rock ; in other cases each of the separate individuals forming the quartz-mosaic contains in its interior a radiating bunch of minute felspar crystals, among which are sometimes intercalated minute needles of hornblende. Ordinary perlitic structures have been noted in a few cases.

To the west, in the Barmer area, the Malani rhyolites present less variety than those around Jodhpur and Siwana, and consist for the most part of compact, dark grey, sometimes black, glassy or pitchstone-like lavas containing porphyritic crystals of white or pink felspar and grains of quartz. Among specimens collected from the Upper Carboniferous boulder bed of the Salt Range is one which corresponds very closely to some of the western Rajputana rhyolites.[3] In contact with the Malani Granite the rhyolite may or may not show alteration, but there is frequently a considerable development of hornblende in the plutonic rock ; at times, this takes the form of comparativly large nests of hornblende with included portions of the groundmass. Near Miniari are some nodular rhyolites composed of a compact, flinty matrix, crowded with nodular concretions up to six inches in diameter, some of which are almost perfect imitations of fossil shells ; some of the nodules contain cavities filled with crystalline quartz and a little calcite.

More basic lavas.—Intercalated with the rhyolites in several places are sheets of less acid type, containing plagioclase felspar and no free quartz, and corresponding to similar andesitic rocks in Sirohi. The balance of evidence seemed at first to be in favour of their being intrusive sills and not interbedded lavas, their relationships being obscured by soil and débris, but borings and well-sinking for water near Jodhpur have since shown, according to Dr. P. K. Ghosh, that these intercalations include intermediate and basic tuffs, whose sub-aerial or sub-aqueous nature proves their contemporaneity with the rhyolitic tuffs associated with them. These more basic rocks include olivine basalt, and the vesicular nature of this rock in one of the borings favours the view that some of it at least represents a contemporaneous flow.[1] The olivine basalts, which contain antigorite after olivine, porphyritic crystals of labradorite and olivine, sometimes show pseudomorphs and small flakes of the same mineral in the groundmass derived either from olivine or augite. Vesicles containing chlorite, chalcedony, calcite and epidote, are abundant in these basalts.

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[1] *Mem.*, XXXV, 84 (1902).
[2] *Rec.*, XXXIV, 164 (1906).
[3] C. S. Middlemiss. *Rec.*, XXV, 34 (1892).

Tuffs.—The tuffs and breccias associated with the lavas appear to be quite subordinate in amount to them, but, as La Touche points out, it is possible that a great part of the sandy plains between the hills of lava may be underlain by these softer rocks, which are as a rule exposed only in slopes at the base of the scarps formed of the harder lavas. " The tuffs associated with the rhyolites are easily distinguishable from them in the field mainly by reason of their lighter colours, their mode of weathering, and their undoubtedly bedded aspect. In many cases the larger fragments and lapilli they contain stand out conspicuously on the weathered surface of the rock." Under the microscope, the matrix is hardly to be distinguished from the groundmass of some of the rhyolites and was evidently formed of the same material blown into dust and subsequently consolidated.[2] The clastic origin of the tuffs, some of the beds of which reach 250 feet in thickness, is proved by the presence therein of the fragments and lapilli of quartz and other minerals as well as of previously consolidated rhyolite, and by the signs of sorting action and rearrangement under water. The specific gravity of the tuffs ranges as low as 2·33 and rarely rises above 2·40 ; that of the rhyolites varies from 2·42 in the softer altered examples to about 2·76 in unaltered specimens.

Andesitic tuffs, found in close association with rhyolitic tuff in well-borings near Jodhpur railway station, are generally green in colour, a result due to the abundant development of chlorite ; vesicles containing chlorite, calcite and epidote are numerous. Acid and basic cycles of igneous activity alternated with each other during the earlier parts of the volcanic epoch. The acid character of the magma from which the rhyolitic tuffs were derived is, in fact, often obscured by the presence of minerals belonging to a more basic magma. Phenocrysts of plagioclase, highly sericitised, may, for instance, be found in appreciable quantity in some cases, giving a dacitic or andesitic character to the rocks. Or again, in some of the rhyolitic tuffs a few crystals of iddingsite and antigorite, apparently pseudomorphous after olivine, have been noted, and have no doubt been derived from some basic magma. The more basic tuffs include twinned crystals of labradorite.

Breccias.—The breccias usually occur in small patches or lenticular bands intercalated with the lava flows. The irregular, angular fragments of various sizes, derived from previously consolidated flows, are embedded in a more or less opaque paste. In an interesting example described by LaTouche, bundles of duplicate fibres have been developed, projecting inwards from the faces of the fragments and at right angles to them, not meeting in the centre but leaving clear linear spaces along which there is usually a line of black granules ;[3] in some cases the fibres curve round minute globulites. The structure is said to be exactly similar to that developed in a piece of artificial glass exposed after its first consolidation to great heat.[1] "The matrix of this breccia is a fine-grained microcrystalline rhyolite, and there is no doubt that it was molten when the chips of already solidified glass from another flow were showered into it, and that they were then partially devitrified by the heat of the surrounding molten glass." Some of the coarser breccias, containing blocks of rhyolite up to three feet across, occur in patches or heaps surrounded by the lava, and may possibly be the remnants of ancient necks filled with agglomerate.

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[1] P. K. Ghosh. *Rec.*, LXV, 540 (1931).
[2] T H. D. La Touche. *Mem.*, XXXV, 89 (1902).
[3] *Mem.*, XXXV, 90 (1902).

Conglomerates.—Bands of conglomerate with well-rolled pebbles are sometimes associated with the tuffs, but elsewhere they are sandwiched in between two lava flows without the intervention of any finer material; they have all the appearance of ordinary river gravels.

Mode of effusion.—The slight amount of disturbance the Malani beds have undergone has been insufficient to bring the base of the formation to the surface, with the one exception already described, and the vents, whether fissures or pipes, lie buried beneath the accumulation of lava or of desert sand. The originally viscid character of the lavas is often illustrated by the uneven and scoriaceous aspect of the surface of the flows, and by the abrupt manner in which they frequently die out. "Some of the sheets are of considerable thickness and extend without any alteration in appearance for several miles, but very often a scarp can be seen to be built up of a number of thin sheets, differing from each other in colour and texture, and rendered more distinguishable from one another by a frequent columnar structure." Several flows can thus be made out, some of them containing fragments of earlier flows.

Owing to the mutual similarity of the flows of rhyolite, of which the bulk of the exposures consist, it is often difficult to make out any dip or sign of disturbance in these rocks. Many dips of 30° and more have been recorded among both the flows and the clastic deposits, however, rising in three or four cases to 45° and 50°. Certain vertical divisional planes in the rhyolite of the large hill immediately south of the village of Nagona, and also of an exposure one mile south of Malgarh —a village to the southwest of Miniari—are largely responsible for the suggestion that rhyolite eruption may have taken place through fissures. In the Nagona area the rock is glassy-looking and almost as fissile as slate. The divisional planes are lines of flow and in plan pursue a wavy direction, generally about N.W.-S.E., flowing sometimes round an included mass of more massive porphyritic rock. In the surrounding hills, patches of a similar fissile rock are frequently met with among the nearly horizontal flows of more porphyritic rhyolite of which the main mass of the hills is composed, and rise through the latter after the manner of an intrusive dyke. There is nothing to indicate that the fissile rock was originally horizontal, and the suggestion has been advanced that the vertical character of the flow-structure may be due to pressure from the sides of a great fissure through which the rock was erupted, and that this may be the site of a vent. The fissile rock, from two to three miles wide, stretches for about six miles from northwest to southeast but may, of course, extend to a greater distance beneath the sand and alluvium beyond the edge of the hills. In support of this theory is brought forward the fact that to the northeast of Nagona there is a general northeasterly dip in the lavas, while to the southwest there is a general dip towards the southwest.[1] A mile south of the village of Malgarh, we find similar vertical lines of flow in the rhyolite, "as though the lava had been subjected to lateral pressure while welling out from a fissure parallel to the range". The lack of concentricity in the outcrops of the lava sheets seems to afford some measure of support for this supposition. Against this idea, however, is the fact that the eruptions were accompanied by explosive outbursts, as is proved by the presence among the bedded lavas of intercalated bands of tuff and breccia produced by the shattering of previously consolidated flows, and it seems more probable that actual eruptions were of the Vesuvian or Puy type characteristic of acid emissions, and took place from central pipes, building up more or less conical piles. Recent work in Rajputana has shown that the rocks of this region have been disturbed subsequent to the deposition of the Lower Vindhyan to a sufficient degree locally to tilt them to a vertical position; this would account for the vertical divisional planes, assuming these and the fissility to be due primarily to lines of flow.

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[1] T. G. Bonney. *Q.J.G.S.*, XLI, 92 (1885).

That the eruptions were sub-aerial in character seems probable from the bands of conglomerate, which include well-rolled pebbles of consolidated lava and have the appearance of river gravels intercalated among the flows. In the small hill at Pati, W.N.W. of Miniari, some 200 feet of purple and greenish, sandy and pebbly beds are conformably overlain by rhyolites which form a precipitous scarp, and there is good reason to believe that they are also underlain by rhyolites. In places, these sandy beds show distinct current-bedding; their topmost member, lying at the foot of the scarps, is a band containing rolled pebbles of rhyolite up to six inches in diameter, the upper part of which is highly indurated, apparently by the heat from the overlying lava flow. Similar sandy and gravelly beds are seen to the north of Siwana, containing rolled pebbles of rhyolite, and forming a band from 20 to 30 feet thick, with sheets of rhyolite above and below. Westwards, these strata, comprising pebble beds interstratified with breccias and felsitic tuffs, swell out to 100 feet; the uppermost pebble bed includes rolled fragments of gneiss and quartzite as well as of rhyolite. These pebble beds are also highly indurated at their contact with a dyke of highly porphyritic rhyolite, 60 feet wide, which cuts them.

NORTHWESTERN JAIPUR, SOUTHEASTERN BIKANER, AND THE MARWAR-BIKANER FRONTIER.

Jhunjhunu.—Forming a connecting link between the main development of the Malani rhyolites near Jodhpur and the widely separated felsites of Tusham in the Punjab are some volcanic beds exposed in a few knolls around Jhunjhunu in the north of Jaipur; these are typical Malani rhyolites with quartz phenocrysts.[2]

Biramsar.—Some 40 miles or so west of Jhunjhunu, within the Bikaner boundary but close to the frontier with Jaipur, is a hill composed of Malani rhyolitic tuffs converted into rough, grey slates, which have been greatly crushed and broken into lenticular plates separated by shear-planes, along which green films of basic copper carbonate occur. The beds are vertical and strike N.N.W.–S.S.E.[3]

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[1] T. H. D. LaTouche. *Mem.*, XXXV, 51 (1902).

[2] A. M. Heron. *Rec.*, LIV, 346 (1922).

[3] A. M. Heron. *Rec.*, LXVI, 43, 132 (1932).

Randisar.—Southwest of the above area and still in Bikaner, the hill north of Randisar consists of black and pinkish brown, massive rhyolites in flows up to 50 feet in thickness, dipping to the east or northeast at angles from 50° to 70°. At the southern end of the hill columnar jointing, in columns between two and three feet in diameter, is well developed. The rocks are little weathered and almost glassy, phenocrysts of felspar being seen with a lens.[1]

Lodsar and Taonra.—Fourteen miles S.S.E. of the last-mentioned locality and just within the Marwar boundary is a group of hills of similarly coloured rhyolites with abundant small phenocrysts of pink felspar. Some non-porphyritic varieties also occur, as well as some associated tuffs. All these rocks, except the tuffs, have a distinct, vertical or steeply-dipping stratification, perhaps due to flow structure ; as a result, they weather like slates, in contrast to the thick massive flows of Randisar hill.[2]

HISSAR DISTRICT, PUNJAB.

The centre and the western side of Tusham Hill in the Hissar district of the Punjab, some sixty miles N.N.E. of Jhunjhunu, are composed of "felsites or micro-quartz porphyries,"[3] which succeed the old sedimentaries without any visible discordance.[4] They dip at high angles with these older rocks,which consist of chiastolite schists and argillaceous beds and are thought to represent the Delhis or Aravallis (see p. 397). The specific gravity of the felsites varies from 2·63 to 2·77, averaging 2·71. In the majority of specimens, there are no porphyritic crystals of felspar but, although not always very obvious to the naked eye, numerous phenocrysts of quartz are sprinkled throughout the matrix ; in these are cavities filled with liquid containing movable bubbles of gas. Some of the quartz phenocrysts are corroded, while others show perfect crystal outlines. One rock specimen shows porphyritic crystals of felspar as well as of quartz, both orthoclase and plagioclase being represented. The groundmass is described as "microfelsitic", and the thin rounded microlites, which are abundant here and there, are at times arranged spherulitically. In some of the rocks are crystals which were thought to be pseudomorphs after hornblende, the replacement mineral being viridite or delessite or some similar product. Magnetite is present and sometimes abundant, and mica is recorded in one or two cases. Fluxion structure is visible in some specimens. The felsites or rhyolites of Tusham differ from the Malani rhyolites in being on the whole less markedly porphyritic and in having mica in the groundmass, but the points of resemblance are many and unquestionable.[5]

A rock from the Khanak hills, three miles northwest of Tusham, is recorded as having a " microfelsitic " groundmass with feeble traces of fluxion structure, corroded quartz phenocrysts, abundant mica and numerous crystals of garnet. Similar rocks are seen in the Nagana hills, seven miles south of Tusham.

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[1] A. M. Heron. *Rec.*, LXVI, 132 (1932).

[2] A. M. Heron. *Rec.*, LXVI, 132 (1932).

[3] The term " felsite " was in the first place applied to the **Malani rhyolites.**

[4] C. A. McMahon. *Rec.*, XVII, 105 (1884) ; *Rec.*, XIX, 164 (1886).

[5] C. A. McMahon. *Rec.*, XIX, 164 (1886).

JECH DOAB AND RECHNA DOAB, WESTERN PUNJAB.

Position and Peninsular character.—Rocks similar to those of the Aravalli range are found in groups of isolated hills piercing the vast expanse of desert and alluvium belonging to the Indus tributaries. There are four separate groups extending from the most important group, the Kirana hills, for over sixty miles to the southeast, through the hills around Chiniot, Sangla and Shahkot.

Of the hills around Kirana, although only 40 or 50 miles distant from the Salt Range, the rocks are totally different from those *in situ* in that range, and approximate more to those of the Aravalli hills, the nearest point of which is 260 miles to the southeast. The Kirana and neighbouring outcrops belong, in fact, to the Peninsula, while the Salt Range is an advanced part of the Extra-peninsular region.

Kirana Hills.—The Kirana hills, some 280 miles northwest of Tusham, in the Jech Doab, form a striking feature as they rise steeply from the alluvium in lines of shattered serrate summits, elongated in the direction of the strike and bare of vegetation. The general strike of the western half of the Kirana hills is N.W.–S.E.; in the eastern half it is at right angles to this. According to Dr. Heron, the peculiar blackness of these hills is due to the thin shining film of iron oxide which coats all long-exposed surfaces and which the scanty rainfall is insufficient to remove.[1] This and the close and splintery jointing which affects all the beds give a uniformly rugged and irregular aspect to the rocks and tend to obscure their differences. Beneath the hard crust, the rocks are rotten and friable and copiously impregnated with hæmatite. Metamorphism has been chemical rather than dynamic and, in spite of the high inclination of the strata, there are no signs of schistosity; even the slates are barely cleaved. Kirana itself rises 1,050 feet above the level of the plain and is a place of pilgrimage.

The predominant rocks of the Kirana hills are hardened shales or slates and somewhat argillaceous, coarse or fine quartzites. The hills are broadly separable into two zones, quartzites to the southwest and shales and slates to the northeast, of a somewhat indefinite N.W.–S.E. line. The general strike of the southwestern half of the hills is N.W.–S.E.; in the northeastern half it is at right angles to this. The significance of this change in strike is not known. The shales are usually green or grey, much impregnated with ferruginous matter along the bedding and the numerous joints. The grey, purplish or reddish quartzites are harsh in texture and carry much iron, disseminated, and segregated near cracks.

Associated with the quartzites, shales and slates, which are said to bear family resemblance to the Ajabgarhs of northeast Rajputana,[2] are thin bands of diabase, probably of an intrusive origin, and thin beds of acid igneous rock, which in some cases can be identified as the effusive rhyolite of the Malani period. It is difficult to distinguish the latter from the quartzites, some of which, judging from the angularity of their constituent grains and the absence of bedding, are in all probability altered tuffs; this applies especially to the quartzites on Ghawala Hill. Now and then, amid the copious secondary products into which the constituent minerals have weathered, the structure of the acid igneous rocks is seen to be that of a rhyolite. Discontinuity of outcrop prevents individual beds from being followed far along the strike, and steepness of dip makes it equally impossible to trace them far down the dip. It is, in fact, often impossible, without microscope sections, to distinguish between quartzites of ordinary derivation, tuffs and acid eruptives.

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[1] *Rec.*, XLIII, 230 (1913).
[2] *Gen. Rep.*, *Rec.*, XLI, 85 (1911).

The phenocrysts of the rhyolite comprise irregular and sub-angular crystals of quartz and much kaolinised orthoclase, together with flocculent, brown scales which are probably the remains of biotite, and green chlorite. The cryptocrystalline groundmass is usually vesicular and yellow in colour. Traces of spherulitic structure can be made out, and certain of the bands are obsidian-like and devoid of phenocrysts.

In the types adjudged as tuffs the grains are angular. A feature of these rocks is the number of small, irregularly-shaped cavities they contain, either empty, lined with hæmatite or filled with chalcedony, and the result doubtless of the removal of some mineral constituent in solution.

Chiniot Hills.—The Chenab flows through two picturesque gaps in the Chiniot hills which form a narrow, broken ridge, striking W.N.W.–E.S.E. in the district of Jhang. The rocks are pale grey, red-mottled quartzites, alternating coarse and fine varieties on the north side, and slaty modifications on the south, dipping from 40° to 60° towards the N.N.E. Under the microscope their true nature is seen to be that of tuffs and volcanic agglomerates, consisting of angular fragments of quartz and devitrified glass in a dusty matrix.

Sangla Hills.—Twenty miles to the east of Chiniot, similar pale grey quartzites form the Sangla hills, on which are situated the brick ruins of a town built by Alexander the Great ; these quartzites are, however, finer in texture and more abundantly stained with red and purple ferruginous matter. They are thinly and regularly bedded, with copious rectangular jointing, and dip at high angles to the east and southeast.

Shahkot Hills.—The strata of the Shahkot hills, southeast of Sangla are still more ferruginous, fine-grained and argillaceous, and are more cleaved and altered than elsewhere ; they are arranged in an iso-anticline.

Comparison with the Malani area.—In comparison with the Malani rhyolites of Rajputana and those of Tusham, the Kirana specimens are much more weathered but are of the same general type. The Kirana and Tusham rocks agree in the presence of small amounts of biotite, which is rare in the Rajputana types.

In their field relationships, the Malani rocks of Rajputana are associated with non-volcanic sediments to a much less extent than are the Kirana, or even the Tusham effusives. Heron suggests that this may indicate a diminution of volcanic activity, passing from south to north, the flows dovetailing into ordinary sediments. Such a conception is supported by the vastly greater thickness of the separate rhyolitic sheets in the south. According to this idea, all the rocks on these hills, whether effusive or sedimentary, would find a place in the Malani series or Lower Vindhyan. An alternative view is that the quartzites and slates of Kirana belong to the Ajabgarh series of the Delhi system, and unconformably underlie the rhyolites and tuffs of Malani age, with which they have been folded, and from which they are not always easily distinguishable. Yet another possibility is that the line dividing the Kirana hills into two zones may represent a line of discordance between shales and slates of Ajabgarh age to the northeast, and the rhyolites, tuffs and quartzites of Malani age to the southwest. The dykes of diabase may correspond to the Lower Vindhyan basic intrusions described elsewhere.

II. SEDIMENTARIES.

The trans-Aravalli Vindhyan sediments, occurring in numerous scattered and usually flat topped outcrops consist of sandstone and conglomerate, succeeded upwards by limestone. The sandstone and conglomerate have been compared to the Kaimur series and the limestone to the Bhander Limestone, but Dr. Heron is not impressed by such supposed resemblances.[1] From his very detailed descriptions, the sandstones agree most closely with those of the Bhander series. Since, however, the beds under comparison belong to two separate basins of deposition, such lithological resemblances may be accidental and of limited significance from a stratigraphical point of view. In degree of induration, lithological character, and relationship not only to the tilted Aravalli beds but also to the presumed Upper Carboniferous boulder beds of Bap, there is a general resemblance to the Vindhyan, but further than this it would be unwise to go, and we may agree with Mr. R. D. Oldham that there can never have been any continuity between the outcrops on either side of the range, and that it would be incorrect to speak of the Marwar beds as outliners of the Vindhyan basin. As Mr. Oldham remarks, " the connection between the two would be similar to that which subsists between the recent deposits north of the Himalaya range and the Indo-Gangetic alluvium".[2]

The trans-Aravalli area has yielded some excellent examples of the so-called " chordophyceous " tracks, believed by Nathorst to have been caused by crustaceans swimming quite close to and almost in contact with the sea-flood (see plate facing p. 516). Some of the slabs collected by La Touche from this area, at Osia, thirty miles north of Jodhpur, are covered with fusiform bodies identical in size and appearance with objects occurring in the Silurian of Portugal and regarded as bearing some relation to the trilobite described as *Cruziana furcifera* d'Orb.[3] Beyond these no determinable organic remains have been found in the Marwar beds, which in some places are warped into gentle folds along axes parallel to the post-Delhi folding. This folding is shared by the underlying Malani rhyolites where these lavas form the floor of the basin. The sandstones, consisting of alternations of finegrained and gritty material, are for the most part reddish brown or are streaked and blotched with this colour. A white band, similar to the pale bands-found in the Upper Bhander Sandstone, and from 10 to 40 feet thick, usually occurs about the middle of the sandstone but is not always present; current bedding and ripple-marking are common features. Pebble layers may occur at any horizon and in some sections are found throughout the whole thickness of the sandstone. Actual conglomerates are frequent and in some places predominate over the sandstones, but are not usually found at the base. In places where the conglomerates predominate, the pebbles are larger than usual and attain the size of a walnut, and sometimes that of a golf-ball ; they are composed of quartz and quartzite. The cherty limestone, except that it is neither argillaceous nor ferruginous, resembles some of the Aravalli limestones ; it is also not unlike the Tirohan limestone of Lower Vindhyan age in Bundelkhand and Karauli though containing more chert and in larger masses. It is quite different from any of the Upper Vindhyan limestones. Except for the chert, which is not minutely disseminated but distributed in bands, lenticles and irregular masses, the limestone is pure and homogeneous. It is a grey, fine-grained, non-crystalline rock, which sometimes gives off an odour of petroleum and, when distilled, yields small quantities of oil and an evil-smelling inflammable gas. A vague stratification can be made out in some sections of it ; the high dip it sometimes shows is due to collapse.

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[1] *Rec.*, LXV, 457-489 (1932).

[2] Man., 2nd. Edit., 106-107 (1893). Dr. Auden, on the other hand, so far as limited observations go, finds that on both sides of the Aravalli the currents which caused the current-bedding structures appear in all cases to have come from an easterly direction, being almost confined to a quadrant of a circle between N. E. and S. E. (Private communication); so far as it goes this uniformity might suggest a single uninterrupted basin of sedimentation, but the implication is not absolutely necessary.

[3] E. Vredeuburg. *Rec* XXXVI, 249(1908).

In two places, Sojat and Khatu, the almost horizontal Vindhyans are clearly seen lying unconformably upon nearly vertical Aravalli slates. Elsewhere, the Vindhyan sediments have been laid down upon a floor of Malani volcanic rocks or of the Malani Granite. Wherever the junction between the sediments and the rhyolites is seen, the beds of both in most exposures happen to be nearly horizontal, but here and there unmistakable evidence of unconformity is to be found. In the scarps north of Jodhpur city, for instance, the sandstones are seen not only resting upon a very uneven floor of the lavas, but in places banked up against denuded and scarped edges of the flows. Moreover, the upper portions of the lavas, where these are exposed beneath the sandstones, are usually seen to be rotten and weathered to a considerable depth down from the ancient land-surface—a feature not observable on the present-day surface of the lavas. Finally, at the base of the sandstones there is frequently a layer of varying thickness in which large blocks of the lava are embedded in silt and grit ; these blocks are not waterworn boulders and are always composed of the same variety of the lava of which the underlying sheet consists, having apparently weathered out therefrom *in situ.* In a few places patches of true conglomerate in the form of waterworn pebbles and boulders of lava and other crystalline rocks, transported from a distance, are found associated with beds of fine, red and green shale ; they occupy hollows in the uneven surface of the lava flows, and underlie the sandstone.[1]

The sandstone formation mentioned in the previous paragraph was named the Jodhpur Sandstones by W. T. Blanford, who found them stretching for 90 miles from Pokaran to Jodhpur though largely concealed beneath the desert sand. He describes these beds, which are to be found for some distance west and north of Jodhpur city, as usually coarse in texture and nearly always of a dull red colour. As a rule, the rock is purely quartzose, but felspar is sometimes present, and in places micaceous layers give the rock a fissile character. It is often current bedded and many of the slabs are ripple-marked. The beds, rolling about at low angles, show no alteration and closely resemble some of the cis-Aravalli Vindhyan sandstones, except that they are somewhat softer.[2] Sir Cyril Fox has no hesitation in equating the Jodhpur sandstones with those of Pokaran, and both with the

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[1] T. H. D. La Touche. *Mem.*, XXXV, 27(1902).
[2] W. T. Blanford. *Rec.*, X, 18(1877).

Vindhyan; he remarks on the resemblance of the Pokaran sandstone with the Purple Sandstone of the Salt Range a formation which, as already noted, may be a trans-Aravalli member of the Vindhyan.[1]

The basal bed, well seen in the group of hills southeast of Khangta, is a dark red freestone, with a layer, an inch or two thick, of sub-angular pieces of white quartz as large as walnuts or hazelnuts, embedded in kaolin and derived from the large but infrequent dykes of quartz which traverse the underlying granite. This freestone, about 15 feet thick, is soft, thick-bedded, fine in grain and usually lighter in colour than the sandstones which succeed it. The granite which here underlies it is evidently not of a type which tends to form pebbles. In these hills the freestone is succeeded by 150 feet of dark reddish brown sandstone, uniform in character, almost pebbleless, with a six-inch band of chert about 80 feet from the base. The most complete section is seen in the inaccessible rock-island which carries the citadel of Khatu, and is described by Dr. Heron.[2] Here the Aravalli slates, which are reached in wells and crop out below the scarp in two places, are overlain by about ten feet of the freestone, an inconstant three-foot bed of conglomerate intervening at one spot. Above the freestone come about 30 feet of soft red sandstones in a steep slope leading up to the base of the main scarp. The lower 40 feet of the latter consist of current-bedded, pebbly grits, at the top of which is a horizon characterised by ovoid siliceous concretions resembling sheep-droppings in size and shape. This is followed by 30 feet of white, flaggy sandstones, which project in places over the pebbly grits beneath and are much used for the carving of very fine perforated window-screens. Above these are 120-150 feet of bright red or reddish purple sandstones with sparse lenticles and streaks of white; these soft, rather coarse, micaceous and current-bedded rocks are the chief component of the Khatu hills, rising in stepped slopes from the white flagstones at their base. Capping these sandstones are 40-50 feet of pinkish white or pale buff freestone with fine brown lines marking the bedding. Being poorly stratified, but having strong vertical joints, this freestone gives rise to mural cliffs surrounding the small plateau which cap the hills. The topmost portions of the hills consist of small cakes of breccia, from five to twenty feet thick made up of angular fragments of chert cemented by silica, with occasional sheets of botryoidal iron oxides; it is probably a residual deposit resulting from the collapse of the chert content of the Marwar limestone. The limestone itself is seen well in the two large hills northwest of Khatu, separated from each other by the village of Barnel.

The finer grades of the sandstone make excellent building material and are very largely used for the purpose in Marwar. The hard sandstone north of Jodhpur city is quarried not only for local purposes but for export to Karachi.

At Pokaran, the Vindhyan sandstones are exposed close to some boulder beds though not visibly in contact with them. La Touche suggests that the boundary between the two rock types is probably a fault, and correlates the boulder beds with those of Bap, 35-40 miles away to the N.N.E., which have every appearance of being glacial in origin and are in all probability of Talchir (Upper Carboniferous) age. W.T. Blanford and R. D. Oldham, on the other hand, were of the opinion that the Vindhyan sandstones of Pokaran overlie the boulder beds unconformably, and Dr. Heron remarks that the description of some boulder beds at Lawa (Lowo), only five miles distant from Pokaran, suggests a basement agglomerate, like that at the base of the Vindhyans near Jodhpur, in which large boulders of the Malani rhyolite, weathered out *in situ*, are buried in silt; smaller rounded boulders near Pokaran itself form a true conglomerate of well-rolled pebbles of the lava and of other crystalline rocks, associated with red and green shales.[1] While the striae on the Bap boulders are indubitably of glacial origin, the boulders of the Pokaran beds appear to be unstriated, with one possible exception which shows polishing and obscure grooving probably attributable to wind action. It is probable, therefore, that the Pokaran beds belong to the local base of the Vindhyan and are not to be correlated with the Upper Carboniferous boulder beds of Bap.

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[1] Private communication.

[2] *Rec.*, LXV, 482 (1932).

The Vindhyan age of the beds under consideration in this section is confirmed by their position with regard to the Talchir boulder beds of Bap. La Touche remarks that, after the eruption of the Malani lavas, a considerable period of time may have elapsed before the sandstones of the Vindhyan system—presumably Upper Vindhyan—were deposited upon them. Whatever may have been the interval separating the two periods, there is no doubt that it marks an entire change of conditions from intense volcanic activity to the placid accumulation of sediments.

How far this trans-Aravalli Vindhyan basin extended to the northwest is not known, as the rocks are concealed beneath the Jurassic of Jaisalmer and the sand of the Thar Desert. To the southwest it does not seem to have extended as far as Balotra or Barmer, for La Touche found in that direction sandstones of much later age resting directly upon the Malani lavas. To the northeast, on the other hand, the basin is known to have reached thirty five miles beyond Bikaner city. Horizontal beds of massive, current-bedded sandstone, similar to the Marwar sandstones as well as to the Upper Bhander Sandstone of the Vindhyan plateau, are quarried at Dulmera, thirty five miles northeast of Bikaner, and supply that city with the handsome building stone so extensively used therein. It is a hard rock, dark red-brown and fawn in colour, often blotched, streaked and spotted in these two tints. Another small bouldery outcrop is seen two miles south of Dhirera Railway Station twenty eight miles N.N.E. of Bikaner city; specimens from this locality show a number of oolitic grains among the sub-angular quartz and felspar grains, and an abundance of heavy minerals, especially of tourmaline and garnet.[2] The total length of this basin from northeast to southwest was, therefore, at least 104 miles.

FORMATION OF THE ARAVALLI RANGE.

The term "Aravalli" is applied by geographers to the N.E.-S.W. range of hills separating the Godwar district of Marwar (Jodhpur) from the State of Mewar (Udaipur), and continuing to the northeast along a narrow tongue of Ajmer-Merwara. In early geological times the range, immensely greater than it is now, extended far beyond these limits to the northeast and to the southwest. When speaking of this ancient chain, it is convenient to extend the name to the former limits of the hills and to their more or less isolated relics in the central part of

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[1] *Rec.*, LXV, 467 (1932).

[2] *Gen. Rep.*, *Rec.*, LXXIII, 26 (1938).

Ajmer, in Kishangarh, Jaipur and Alwar in one direction, and to the more extensively hilly tracts in central Mewar, Sirohi, Palanpur, Dungarpur, Banswara, Idar, and Danta, in the other.

Throughout the Indian Peninsula the metamorphosed Archæan areas must include many instances of the roots and relics of ancient mountain systems, but with insignificant exceptions, all have been worn down to undulating plains or plateaux. Accepting Dr. Heron's conclusion that the Delhi rocks belong to the Purana group, it is natural to infer that the Aravalli chain owes its prominence chiefly to the fact that it belongs to a stage of uplift much later than that of the vanished mountains now reduced to featureless plains. As already stated, the Aravalli is the only range of importance in the Peninsula which owes its existence in the first place to the severe folding to which its rocks were subjected, the axes of the folds coinciding generally with the direction of the range. The relationships of this range with the main Vindhyan basin are matters of special interest.

Between the almost horizontal Vindhyan sediments of the plateau and the ancient slates forming the core of the Aravalli chain, there stretches a narrow strip of Vindhyan beds which show signs of disturbance and have evidently been affected by a later phase of the earth movement which was responsible for the formation of the Aravalli range. This strip is more or less enclosed between two lines of faulting, but the line forming the southeastern boundary in the Karauli area, when traced southwestwards, becomes the northwestern boundary in the Bundi State. The disturbed Vindhyan strip is thus, as it were, echeloned with respect to the line of faulting common to the two areas, and is characterised by strike ridges parallel to the axes of dislocation and folding in contrast to the plateau country to the southeast. Along the northwest side of the strip, the wreck of the Aravalli range is represented by numerous outcrops of highly-dipping slates and schists, many of them isolated by Recent alluvial deposition.

In the Karauli area, the above-mentioned marginal strip of Vindhyan beds averaging some 12 miles across, is corrugated into two broad synclines and anticlines ; northeast of this the rocks between the two faults are folded into a mutually contiguous syncline and anticline. Southwestwards, from the Karauli area, in Bundi State, the folding becomes tighter, the beds are disturbed by additional faulting, and the average width of the strip is reduced to less than four miles.

The echeloned line or zone of faulting referred to above is known in general terms as the Great Boundary Fault of Rajputana, and has every appearance of denoting the limit of deposition of the Vindhyan sediments belonging to the main Vindhyan basin against the foot of the old Aravalli chain. Disregarding the distant trans-Aravalli Vindhyan exposures which belong in all probability to a separate basin of deposition, no outliers of definitely identified Vindhyan rocks occur on the northwest side of the fault zone, with apparently one exception. The exception to this clean division of the rocks is a small outlier on the northwestern side of the faulting S.S.E. of Hindaun, consisting of Kaimur sandstone and the Tirohan Breccia. Other supposed outliers have been recorded but, in the case of some of them the position of the fault is not certain, and in the case of others the identification of the outlying rocks is not beyond suspicion.[1] In Karauli, outlying strips of the younger rocks are found between the reduplicated ends of the fault, and show a much greater degree of disturbance, and in some cases greater alteration than do their equivalents on the downthrust side of the faulting. To a very close degree, therefore, the Great Boundary Fault of Rajputana is a line of distinction between highly-folded and metamorphosed ancient rocks on one side and gently dipping unaltered younger sediments on the other.

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[1] Where the boundary of these outlying exposures is a faulted one, one might suspect the presence of tectonic "windows".

To recapitulate, there extends along the northwestern margin of the main Vindhyan basin a fault or thrust zone which coincides approximately with the old boundary of Vindhyan waters. In the immediate neighbourhood of this faulting the Vindhyan sediments show corrugation or disturbance—sometimes of a severe character—but a few miles distant from the fault they assume a practically horizontal position and stretch in a comparatively undisturbed state for many miles to the southeast.

If we are correct in assigning the Delhi rocks to the Purana, it must have been the closing phase of that era which witnessed the initiation of the great mountain range of which the present Aravallis are but the wreck. This range became and remained for a very long time the principal feature of this end of the old Gondwana continent. To the northeast it reached at least as far as the Delhi "Ridge" and possibly as far as what is now part of the Himalaya, for the most conspicuous instance of transverse strike in the old rocks of the latter mountain system lies in a line with the Aravalli range. This belt of transverse strike in the Himalaya extends, with one interruption in the neighbourhood of Ranikhet, for some 60 miles into the Hills and is associated along one section with folded and crushed rocks and along another with a transverse fault.[1] The crushing is described by Middlemiss as of a kind which has taken place in the cold and solid state of the rock[2] and, although such transverse features in the Himalaya may elsewhere be due to other causes, they may, with some show of reason, be relics of the old Aravalli compression when found along the strike of the Aravalli range. It should be noted that these transverse Himalayan strikes cease at the Sub-Himalayan belt of Tertiary rocks, where they are abruptly replaced by the normal W.N.W.-E.S.E. strike. Indications supporting those reported by Middlemiss have been noted by Auden in the orientation of phenocrysts and of lenticular and linear structures in the gneissic granite at Landsdowne in British Garhwal—a granite which, it is true, has been regarded by many as provisionally Tertiary but which is probably much older and nearer the Carboniferous in age. N.E.-S.W. directions are recorded by the same observer in the tectonic elongation of pebbles in the Jaunsar conglomerates, and also in the fold ripples of the phyllites and the schistosity of the quartz schists of the same series in the Simla-Chakrata area.[3] The Jaunsar rocks are possibly Devonian in age, and orientation along Aravalli directions has been observed in Himalayan beds up to but not above the Blaini formation, which there is good reason to believe belongs to the Upper Carboniferous, an age not very dissimilar to that of the Landsdowne granite. If we are to accept such anomalies in strike and orientation as Aravalli features, we must conclude that the Aravalli compressional movement persisted—perhaps with a much subdued effect—till long after the Vindhyan period, and only ceased towards the end of the Carboniferous. A further fact suggesting an ancient northeastward continuation of the Aravalli into the Himalayan region is the dying-out of the fossiliferous Parahio (Cambrian) beds of Spiti in a southeasterly direction—*i.e.*, towards the supposed extension of the Aravalli chain. Before leaving this subject, it is perhaps worthy of mention that the great mountain knot in Tibet, which forms the cradle of the Manasarowar Lakes and from which flow the Sutlej and Indus to the northwest and the Tsangpo-Brahmaputra to the southeast, is also in line with the Aravalli belt of compression.

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[1] These strikes are more or less N.-S. and not quite at right angles to the normal strike of the Himalayan range ; in fact, they make an angle of not much more than 60° with the latter.

[2] *Mem.*, XXIV, 126 (1890).

[3] *Rec.*, LXVI, 467 (1932).

How far to the southwest the old range extended it is impossible to say definitely, since the rocks are covered by the alluvium of the Saraswati, Sabarmati, Mahi and Narbada, by the Mesozoic sediments and lavas of Kathiawar and Cutch and by the waters of the Arabian Sea. Upon this point the soundings taken by the John Murray Expedition in 1933 have perhaps some bearing. These investigations showed the existence beneath the Arabian Sea of a submerged mountain range, rising 10,000 feet above the general level of the sea-bottom and trending in a southwest direction towards the island of Socotra. On the northwest side of this range, which one is tempted to suggest, may be a relic of the Aravalli or of a branch thereof, submerged by the foundering of part of the Gondwana continent after the outpouring of the Deccan Trap, is a level plain, some 1,850 fathoms below sea-level, bounded to the north by another less lofty sunken mountain range extending westwards from the vicinity of Karachi to the entrance to the Gulf of Oman, parallel to the Makran coast. Southeast of the higher range is a deep narrow valley, with a depth of 2,000 fathoms, having a steep slope on its Cutch and the Kathiawar coast.

Another submarine ridge runs due N.-S. through the Laccadive, Maldive and Chagos islands, and may perhaps represent another branch of the range; such a conception is supported by geodetic anomalies, which are similar in the Aravalli and Laccadive areas. The behaviour of the submarine ranges below the Arabian Sea is in harmony with the fan-like splaying of the Aravalli strikes in southern Rajputana and northern Bombay.

One of the main structural features of the Aravalli range is the Great Boundary dislocation which in a general way, and disregarding the narrow belt of disturbed Vindhyan, separates the gently-lying deposits of the main Vindhyan basin on the southeast from the highly-folded and contorted beds of the more ancient systems on the northwest. It has been traced throughout its entire visible length from where it sinks below the Jumna alluvium near Fatehpur Sikri in the northeast to its disappearance beneath the Deccan Trap on the frontiers of Mewar and Partabgarh in the southwest, a distance of between 250 and 260 miles. The faulting is seldom or never a clean-cut thrust but is frequently spread over a belt of some considerable breadth. Sometimes these planes of movement diverge widely, with large blocks of unfractured country in between; in other places they are condensed into a band of shearing and crushing. The fracture is believed to be of a reversed nature, hading to the northwest, though very little definite field evidence in favour of this conclusion has yet been adduced. Its maximum throw or thrust is estimated to be at least 5,000 feet. For long distances, this throw appears to show very little variation; throughout its whole length in the State of Bundi, for instance, a distance of 70 miles, the Aravalli (Gwalior) rocks on the one side are brought against either the Upper Bhander sandstone or the Sirbu Shales of the Upper Vindhyan formation.

As already explained, the Great Boundary dislocation, throughout a large part of its course consists of two major faults, usually from six to twelve miles apart, and echeloned on one another for a distance of 70 miles or more in the neighbourhood of Karauli, through which town the most southeasterly of the faults passes. Here the direction of the faults is parallel to the axes of folding of the region, and is N.E.-S.W. Some at least of the minor cross faults are probably unconnected with the main tectonic movements.

The northwestern of the two faults is not so well seen. Actual sections when visible are described as showing a steep, almost vertical, hade ; in one place, however, inversion has been noted, the Tirohan Breccia overlying the Kaimur Conglomerate at an angle of 45°. A short distance from the fault, the Upper Bhanders are seen to be tilted and form a remarkably straight and almost uninterrupted edge to the Bhander plateau, over which they occur in their normal more or less horizontal position. East of Loharra the fault, when followed southwestwards, divides into two branches which, after causing a repetition of the three Vindhyan series, unite again further southwestwards into one plane of fracture. The northwestern fault decreases in throw towards the southwest and appears to die out beneath the alluvium west or northwest of Ranthambhor ; to the northeast its effects have been traced to within a few miles of the Jumna.

The more southeastern of the two faults commences in Karauli, in the plateau of Upper Bhander Sandstone, as two converging branches which meet a distinct valley has been excavated along the line of disturbance. Although conveniently spoken of as a single fracture, it is probably more of the nature of several close parallel dislocations distributed over a breadth of about a quarter of a mile. Towards Karauli, as the throw increases, lower and lower horizons are successively thrust from the northwest over the Upper Bhander Sandstone ; in this way, the Lower Bhander Sandstone, the Bhander Limestone, the Upper Rewah Sandstone and the Tirohan Limestone and Breccia are each of them brought into close proximity or into actual contact with the Upper Bhanders, but there are slight irregularities in the throw of the fault, and the appositions are not always successive. A ferruginous breccia sometimes marks the position of the fault in Karauli, and crushing and brecciation are often seen along its line. Where the Aravalli (Gwalior) quartzites are brought into juxtaposition with the Sirbu Shales, the throw of the fault must be at least 4,000 feet ; along this section large masses of a white fault-breccia are sometimes seen, composed of fragments of the Aravalli quartzite in a granular quartzose cement. Beyond Ranthambhor, the fault forks into two branches which enclose between them part of an anticline in which is exposed an almost complete sequence of the Upper Vindhyan from the Panna Shales to the base of the Sirbu Shales.

In the State of Bundi where, as usual, the general strike of the Upper Vindhyan coincides with that of the Aravalli rocks to the northwest, the Great Boundary Fault is a continuation of the more southeasterly of the two faults in the Karauli area and is a prominent structural feature. Here again its position in the opinion of Coulson, cannot differ greatly from that of the old Vindhyan shoreline.[1] In the northeast corner of the State, there is very complicated cross-faulting.

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[1] *Rec.*, LX. 185 (1927).

At Antarda there is clear evidence of the Boundary Fault dividing into two branches, the southeasterly of which has been traced for a distance of 14 miles before dying out. The northwesterly branch thus becomes the main Boundary Fault. At Satur it suffers a displacement, the effect of a cross-fault. For about a mile in the neighbourhood of Bhojgarh, it consists of several parallel faults. South of this, faulting is less important and displacement has been taken up to a greater extent by the folds. There are many minor faults in Bundi, some of which unite with the Boundary Fault; one of these has been traced for 40 miles and has brought the Jhiri and the Panna Shales against the Upper Bhander Sandstone.

From Tikarde, immediately north of Bundi city, to beyond Mandalgarh in Mewar, the Great Boundary Fault is marked by the so-called " Datunda quartzite ", which appears to be merely a line of wedges of shattered Upper Bhander Sandstone included within the fault or within a series of parallel faults. From Mandalgarh to Chitor, the general strike of the Vindhyan folds is no longer parallel to the fault but oblique to it, various members of the Vindhyan succession abutting in turn against the Aravallis or the Bundelkhand Granite.[1] At Chitor, this fault takes a southward trend and leaves the Vindhyan outcrop, passing, so far as poor exposures show, just to the east of the Sawa grit and shales which are in consequence much crumpled and frequently inverted.

The Great Boundary Fault of Rajputana must be regarded as one of the results of the earth movement from the northwest which folded up the pre-Aravalli, Aravalli and Delhi rocks into the great mountain chain of this part of Gondwanaland. As already shown, the highly disturbed Aravalli beds have been brought, in places, into contact with the almost horizontal Upper Bhander Sandstone, and Mr. R. D. Oldham has called attention to the difficulty there would be in accounting for a fault of so great a throw, were it necessary to assume that the thrust was entirely subsequent to the deposition of the Vindhyans which, except in the immediate neighbourhood of the fault, show little or no disturbance.[2]

To Oldham we owe a highly suggestive description of the close analogy between the formation of the Aravalli chain and that of the Himalaya. Along a large portion of the foot of the Himalaya, on the downthrow side of the " Great Boundary Fault " of the range, there is a strip of upper Tertiary beds which show disturbance but to a less degree than do the older rocks on the upthrust side. The equivalents of these beds are believed to be present under the Recent alluvium of the plains and in more or less conformable relationship thereto. For the purpose of our analogy, therefore, these upper Tertiary beds and the Indo-Gangetic Alluvium, of which they are merely the forerunners, may be treated as one continuous series of deposits. Bearing this in mind and ignoring local complications, it will at once be apparent that the boundary between these young sediments and the ancient Himalayan rocks exhibits very much the same features as does the boundary between the Vindhyans and the older rocks of the Aravalli range. When the Himalayan thrust, which is still proceeding, will have ceased, when the deposition of silt upon the Indo-Gangetic plain will have risen to still higher levels and when the Himalayan chain, including its foot-hills, will have undergone ages of denudation equivalent to those which have laid bare the roots of the Aravalli structure, the resemblances of the one to what the other now is will be still more striking. What is found in Rajputana today will characterise the future Himalaya; in a more conspicuous and clearer degree, the beds of the younger system will be seen lying in contact with highly-disturbed rocks of much more ancient date along a great line of faulting to the north of which will lie a broad exposure of the wreck of a mountain chain.

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[1] *Gen. Rep., Rec.*, LIX, 99 (1926).

[2] Man. 2nd Edit; 103 (1893).

In the case of the Himalaya, the fault, which may be conceived as a thrust from the north, has been gradually formed *pari passu* with the deposition of the Tertiary and Recent sediments of the Himalayan foot-hills and Indo-Gangetic plain. The process, in fact, is not yet completed; the thrust is still proceeding and in some places also the deposition of silt upon the plain. This series of sediments as a whole, dating from an early part of the Tertiary era to the present day, is contemporaneous in its origin with the elevation of the Himalaya and has been formed of the débris of that range. The piling up of the Himalaya has not been limited to any particular series of the Tertiary, or Pleistocene, though it seems to have been greater at certain times than at others, and has persisted till Recent times. The line of the thrust in question is approximately the northern boundary of the sediments of the younger system, and has, for that reason, been called the Great Boundary Fault.

There are some grounds for inferring that the similar structure and association in the case of the Aravalli range indicate a similarity of origin, and that the great Vindhyan spread of Central India is formed of deposits which bear the same relation to that range as the Indo-Gangetic silts and their forerunners do to the Himalaya. The inference is of importance since it would fix the period of the formation of the Aravalli range as contemporaneous to some extent with the deposition of the Vindhyan rocks that were produced from its débris, and would place the original limit of deposition not far from the present limit of the Vindhyan outcrop.

The lack of organic remains in the Vindhyan beds might to some extent be due to the scarcely diminished porosity of more or less unfolded strata, raised at an early period above sea-level and exposed to the solvent action of circulating meteoric waters. Such a suggestion, however, does not commend itself as entirely adequate, and it seems more likely that the unfossiliferous nature of the sediments is a result of the conditions of deposition. The beds appear to have been laid down in a broad belt occupying the angle between the N.E.—S.W. Aravalli range and the E.N.E.—W.S.W. barrier of gneiss which is believed to have stretched across the Peninsula. Signs of an arid climate are not wanting and the Vindhyan silts may have accumulated under conditions alternating between fresh water and abnormally saline conditions. The belt of sedimentation narrowed towards the southwest in the angle between the Aravalli hills and the gneissic ridge, suggesting the source of a large river from this direction. Indian coasts of the old continent, which at that time included much of the Peninsular area, may well have been fringed with volcanoes whose lavas and ashes have been recognised in western Rajputana, western Punjab, the Son valley, and the Chhattisgarh area.

The scattered exposures of supposed Vindhyan rocks to the northwest of the Aravalli range in Marwar belong to a basin of deposition independent of and in all probability unconnected with the main Vindhyan basin on the southeast side of the range. Towards the end of the Vindhyan period, a local depression seems to have formed on the northwestern side of the Aravallis in which these sandstones and limestones were laid down, stretching for an unknown distance to the northeast and northwest but not as far as the southern half of Marwar in a southerly direction.[1] In the light of Oldham's analogy, these beds and their relationship to the Vindhyans on the southeastern side of the Aravalli correspond to the Tertiary and Quaternary deposits on the northern flank of the Himalaya and *their* relationship to the Indo-Gangetic alluvium and its antecedents. The distance between the edges of the two basins—so far as modern boundaries indicate—is much the same in the two cases ; that in Rajputana, about 90 miles, being a little less than that in the Himalaya, about 110 miles. From the width of the Aravalli and Delhi exposures, from the severity of the plication, contortion and thrust-faulting, from the extent and intimacy of the igneous injections in the Delhi rocks, and from the degree of metamorphism exhibited by many of the latter, the impression is given of a mountain range which in Rajputana, although perhaps a little inferior in height and width when compared with the present Himalaya, must have been of the same order of magnitude and importance.

The conspicuous convexity of the Himalaya towards the south, *i.e.*, towards the direction in which the rocks were thrust, is not paralleled in the case of the Aravalli of Rajputana for the simple reason that the old shield of Bundelkhand Granite, against which the Aravalli and Delhi rocks were forced by the movement from the northwest or west, projected in a blunt promontory somewhere in the neighbourhood of Chitor, where it formed a wide nodal area of obstruction to the advance of the rock-waves. The latter curve round this nodal promontory just as the Himalaya-Hazara rock-waves curve round the Muzaffarabad syntaxis of Kashmir, the only difference being that the obstruction in Kashmir seems to have been much more acute. As will be seen in the case of the Himalaya, wherever such nodal points occur, the rock waves naturally assume a concave shape towards the direction in which they are being impelled. Such a concavity—in this case towards the east or southeast—is clearly seen around Chitor where there is a gradual and constant swing-round of the strike. Of the convexity of the strike towards the east, which we should expect in the beds north and south of the Chitor syntaxis, there are, admittedly, only faint indications. To the south of Chitor, the Vindhyan boundary is for the most part concealed beneath the Deccan Trap. A faint convexity can be made out in places—for instance to the southeast of the city of Tonk—but the strike scheme may be complicated by overthrusting, by the presence of additional unimportant nodal points, as well as by the transverse ridge of gneiss, and it is also possible that the original trend of the beds has been to some extent modified by the much later Himalayan movement whose influence is likely to have affected to some extent the northern margin of the Peninsula.

One difference in the two parallels, as remarked by Fermor, is the distinctness of the Vindhyan stages and the wide extent of the majority of them, as compared with the Himalayan Tertiary and Quaternary deposits.[2] This contrast, however, is of negligible magnitude and must not be exaggerated, for most of the Himalayan Tertiary stages can be traced for long distances, just as, on the other hand, some of the Vindhyan stages are not always readily recognisable. The Vindhyan system also includes at least one important limestone, but this can be matched, though somewhat inadequately, by the thin Subathu limestone of the Himalaya. There are indications that the foredeep fronting the Himalaya was occupied at first by a marine gulf, which became subsequently filled up with river sediments. The foredeep in front of the Aravalli also seems to have been initially of a marine character; possibly there were oscillations between marine and sub-aerial conditions in Rajputana, but the former perhaps occupied a somewhat larger proportion of the Vindhyan period than they did of the Tertiary-Quaternary succession in the Himalayan region. In both regions sub-aerial conditions are thought to have predominated.

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[1] T. H. D. La Touche. *Mem.*, XXXV, 29 (1902).

[2] *Rec.*, LXII, 400 (1929).

It is at any rate safe to assume that, like that of the Himalaya, the rise of the Aravalli range extended over a considerable period. The orientation of structures in the Delhi calc-schists and of phenocrysts in the Erinpura Granite is suggestive of early movement perpendicular to the general direction of the Aravalli chain as early as the Purana era.[1] Coulson concludes that in Sirohi most of the folding of the Aravalli and Delhi rocks took place prior to the intrusion of the Erinpura Granite, but the fact that the granite does in places show foliation proves either that the granite magma was under considerable pressure while still viscous or that the compressional force continued in Sirohi after the intrusion. That the bulk of the folding in some sections of the range took place before the last phases of the Erinpura intrusion is considered to be shown by the fact that the final bosses, which are characteristic of the southwestern end of the chain, especially in Idar and Danta, are unfoliated and must have welled up quietly under no strong compression and escaped any severe subsequent tangential pressure. It is the earlier Erinpura intrusions of the northeastern end of the Aravalli chain—in Ajmer, Jaipur and Alwar—which are foliated.

Nevertheless, the Upper Vindhyans, along their boundary with the Aravallis and Delhis, show unmistakable disturbance in the form of folding and faulting and even to some extent of metamorphism. There must, therefore, have been a persistence or recrudescence of the movement which not only disturbed the Lower Vindhyan (including the Malanis), but was locally intensified along the vicinity of the Great Boundary Fault, affecting all series of the Upper Vindhyans.

The Malani suite of intrusions, on the other side of the range, show no foliation, but some disturbance; these facts support the view that most of the upheaval preceded the Malani epoch but that movement continued subsequently. On the northwestern flank of the range in Sirohi, the junction of the Aravallis with the Erinpura Granite coincides with what was almost certainly a plane of movement during the late phase of the earth movements which accompanied the intrusion of the Erinpura Granite. Along this plane, in the neighbourhood of Isri, the younger Malani Granite found a relatively easy path and stoped its way quietly into both the Aravalli schists and the Erinpura Granite; this old junction surface may have played some part in the outpouring of the Malani rhyolitic lavas.

To sum up, therefore, the folding movement which produced the Aravalli range commenced towards the end of the Delhi period, and had begun to wane by the close of the Erinpura Granite intrusion, but continued during Vindhyan times and did not cease till at least the end of the Upper Vindhyan. It is probably safe to infer that the bulk of the uplift was coincident with, and the accompaniment of, the intrusion of the Erinpura Granite. It is not unlikely that during Vindhyan times the folding was to some extent replaced by thrusting. There is some reason to believe that, at the northeastern end of the range at least, the compressional movement was prolonged or suffered a recrudescence which has affected Devonian or Carboniferous rocks. The result of the earth movements which in India folded and compressed the Purana and older rocks of the Aravalli mountains and later on affected the fringe of the Vindhyan basin has been described as the birth of the Gondwana continent, part of the north coast of which coincided more or less with the line of the Himalaya.

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[1] J. B. Auden. *Rec.*, LXVI, 468 (1932).

CHAPTER XV

CAMBRIAN AND POSSIBLE EQUIVALENTS.

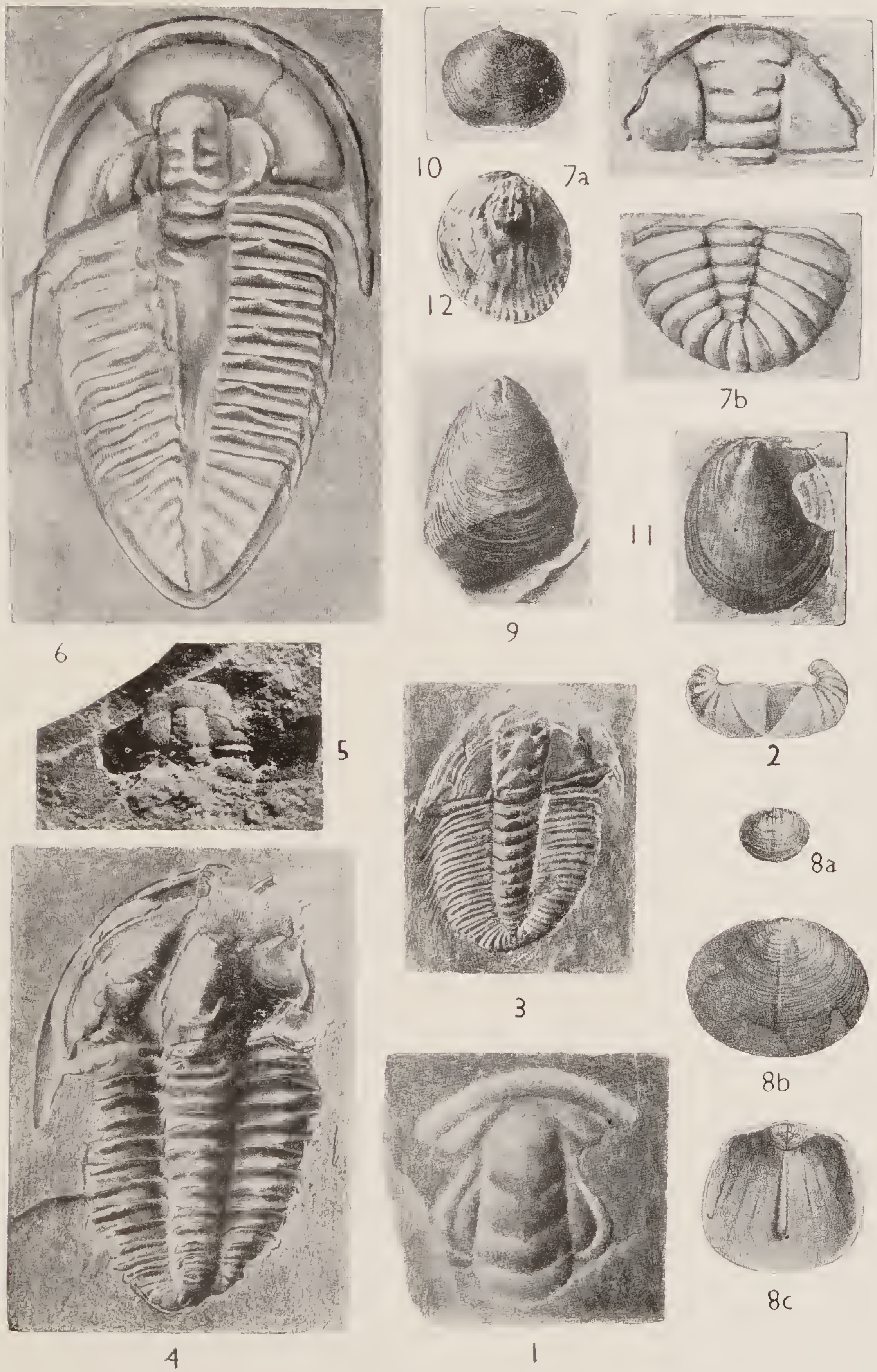
Distribution. **The Salt Range:** Distribution and subdivision—Saline series;—Jhelum series—Isolated occurrences at Chittidil and Chhidru—The Purple Sandstone—Kussak stage—Jutana stage—Baghanwala stage—Faunal relationships. **Trans-Indus continuation of the Salt Range. Kangra district, Punjab:** Subdivision; Parahio series; Subdivision and fauna of the Parahio series; Character of the fauna and its relationships; Age of the Spiti beds; Upper boundary. **Kashmir:** Lie of the ancient sedimentaries; Graywacke group; Relationship to the Dogra Slates; Lower Cambrian; Middle and Upper Cambrian; Fauna; Age and correlation of the beds. **Burma: Bawdwin Volcanic series**—Position and relationships: Age—Composition—The lavas—The tuffs—Mohochaung—Myitkyina—Southern Shan States. **Pangyun series: Yunnan and Tonkin. Cambrian Geography.**

Distribution—In Extra-peninsular India, the presence of Cambrian rocks has been proved in three areas—the Salt Range of the Punjab, certain parts of Kashmir, and the Spiti valley of the Punjab Himalaya—by the discovery of Cambrian fossils. It is also probable that the system is represented by rocks which have so far proved devoid of recognisable fossils in other parts of Kashmir, and in Upper Burma. As already noted, it is not impossible that the Dogra Slates of Kashmir, the Simla Slates of the Punjab Himalaya, the Attock Slates of Attock and Hazara, and their partial or approximate equivalents, the Chails and the Chandpurs, are also of Cambrian age instead of belonging to the Purana, under which heading they have been provisionally placed. The Vindhyan sequence described in the previous chapter, and more especially the uppermost stage of the Lower division thereof, may be of Cambrian age (pp. 498-99).

THE SALT RANGE.

Distribution and Subdivision.—The Salt Range, lying in the Punjab districts of Jhelum, Shahpur and Mianwali, and fronting the river Jhelum, is little more than the scarped southerly margin of the Potwar plateau, stretching from the bend made by the Jhelum river at the cantonment of that name westwards to the Indus opposite Kalabagh. From Jhelum town to a point nearly opposite to the culminating point of the scarp, Mount Sakesar, the Jhelum river flows along or close to the foot of the range before turning southwards; beyond Sakesar the Salt Range scarp takes a sharp bend northwestwards to the Indus. Its eastern end is complicated by displacement as well as faulting. The dry and sun-burnt face of the scarp, which radiates much heat, is characterised by fan-shaped accumulations of detritus at the mouths of the gorges draining the range; these fans encroach upon each other to form a stony belt carrying a stunted jungle which but adds to the sterile aspect. The deeper ravines such as those of the Nila Wahan, Sardahi and Nursinghpur, are, however, not without beauty. The range is named after the great salt fields it contains, and the age of this salt has presented one of those problems which from time to time create a kind of civil war in the geological world. To discuss all the various views put forward concerning the age and origin of the salt and salt marl and their relationship to the salt deposits of Kohat, would fill a small volume and cannot be undertaken in a work of this kind.

Briefly, there are four salt-bearing areas in northwest India: (i) Mandi State, forming part of the Punjab Himalaya; (ii) the Punjab Salt Range; (iii) the trans-Indus continuation of the latter; and (iv) the Kohat salt fields.



CAMBRIAN FAUNA.

1. *Redlichia noetlingi* (Redlich). 2. *Pseudotheca waageni* Redlich. 3. *Oryctocephalus salteri* Reed. 4. *Ptychoparia spitiensis* Reed. 5. *Chittidilla plana* King. 6. *Anomocare hundwarense* Reed. 7 (a). *Tonkinella kashmirica* Reed (cranidium). (b). *Tonkinella kashmirica* Reed (pygidium). 8 (a, b, c). *Neobolus warthi* Waag. 9. *Lingulella spitiensis* Reed. 10. *Acrotreta parahioensis* Reed (brachial valve). 11. *Acrothele praestans* Reed (pedicle valve). 12. *Acrothele vertex* Reed (pedicle valve).

G. S. I., Calcutta.

Of the age of the salt in the Kohat fields, which lie north and west of the arcuate ranges continuing the Punjab Salt Range across the Indus, there can be no doubt; it is accepted by all as Tertiary, and either Palæocene or Lower Eocene. The salt in Mandi, one of the Simla Hill States, is also generally accepted as of the same Tertiary age. With regard to the salt in the Salt Range and in the scanty isolated outcrops along the same line of strike west of the Indus, the view put forward by Wynne after a detailed survey of these areas as well as of the Kohat region, was that, while the Kohat salt was Tertiary, that of the other two regions was older than the beds containing Cambrian fossils (at that time pronounced as "Silurian"). This Cambrian or pre-Cambrian age was not accepted by all, and the results of Dr. E. R. Gee's recent re-survey seemed at first to support the view that the salt of all three regions was the same and, like that of Mandi, Tertiary.[1] During that re-survey, however, two planks were added to the argument favouring a Cambrian age. One of them was the failure by Dr. Gee, after exhaustive search, to find *Nummulites* or other Tertiary fossils occurring indigenously in rocks definitely associated with the salt and salt marl, especially in the shale bands intercalated among the deposits of gypsum. The other was the discovery of Cambrian fossils in Persia, in beds said to be closely associated with the salt deposits of that country—salt deposits which at first had been pronounced by Dr. Pilgrim to be of some age between Upper Cretaceous and Middle Eocene, and subsequently as possibly as old as the Trias.[2] Dr. Gee's final views coincide approximately with those of Wynne and uphold the Cambrian or pre-Cambrian age of the Salt Range salt, but still more recent discoveries by Prof. B. Sahni and Mr. B. S. Trivedi have re-opened the question.

The Salt Range has been affected by compressional stresses of some severity persisting to a late phase of the Tertiary period and resulting in complicated overthrusting and tear-faults. The sequence includes in its lowest portion an extensive succession of apparently conformable strata, nearly 3,000 feet in thickness, which have been divided into the following subdivisions in order of physical superposition :—

		In feet
Jhelum series	(iv) Baghanwala or "Salt Pseudomorph" stage . . .	450
	(iii) Jutana or Magnesian Sandstone stage	250
	(ii) Kussak or Neobolus Shale stage	100
	(i) Khewra or Purple Sandstone stage	450
Saline series	(c) Gypsum-dolomite stage	at least 200
	(b) Salt Marl	,, ,, 750
	(a) Gypseous Marl	,, ,, 500

The complete sequence is only seen in the eastern part of the range, where it remains very constant over a wide area, while overlying younger formations gradually diminish in thickness.

The base of the range is occupied very largely by the Saline series, which includes the salt marl, salt and gypsum. In the eastern half of the range, this series is overlain by the Purple Sandstone; in the west, it is succeeded by the Talchir Boulder Bed of Upper Carboniferous age, except in the vicinity of the Indus at Kalabagh where Siwalik beds immediately succeed it.[3]

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[1] A brief summary of the various hypotheses put forward was made by the writer some twenty years ago when the balance of evidence seemed in favour of the view that the salt on both sides of the Indus was Tertiary. See *Mem.*, XL, 358-371 (1920).

[2] Hormuz series. *Mem.*, XXXIV, Pt. 2, 16 (1908); *Mem.*, XLVIII, Pt. 2, 19-24 (1925).

[3] E. R. Gee. *Current Science*, II, 460 (June, 1934).

Saline Series.—The term " Saline series " was employed by Wynne to include the salt marl, rock-salt and gypsum of the Salt Range and Kalabagh. Besides occupying the southern margin of the Salt Range, it has been recorded in one or two isolated areas on the north slope of the latter ; on the other side of the Indus it is seen not only at Kalabagh but again as two isolated patches a few miles to the north of that town.[1] Possibly the gypseous beds of Kingriali at the southern end of the trans-Indus Khasor hills,[2] and perhaps the gypsum beds at Umar Omar Khel in the same range, belong also to this series.

The predominating member of the Saline series is a gypseous marl (*kalar*) of a bright scarlet to dull purple, tough but not hard and, in spite of its great thickness, with a notable absence of stratification or colour-banding and of any of the coarser forms of sediments. In places, it acquires an appearance of stratification from contained beds of gypsum and rock-salt, a few layers of dolomite, some beds of sandy dolomite in its lower parts and, near Khewra, a six-inch band of bituminous shale and some irregular patches of an obscure, dark purple, dioritic trap. Near Choha and Warcha Mandi, the sequence includes bedded, gypsiferous, light grey and greenish clays, flaggy dolomite and low grade oil-shale, intercalated among which are several thin bands of soft, pink sandstone and some flaggy gypsum ; Gee notes that these beds are undoubtedly a normally stratified sedimentary sequence.[3] The marl itself is composed of gypsum and red clay, with a certain amount of calcium and magnesium carbonates in about equal proportions, and a little alumina and ferric oxide. It does not disintegrate with hydrochloric acid, but when powdered effervesces, the carbonates, alumina and iron oxide dissolving, and a reddish mud of clay and calcium sulphate remaining. The colour of the marl is due chiefly to the ferric oxide. The red Salt Marl is seen in the inliers north of the range and in the disturbed area of Kalabagh, but further west is absent or represented by inconspicuous greyish clays.

From a quantitative analysis of the Red Marl made by himself, Dr. H. Warth has attempted an interesting reconstruction of the minerals present as follows :—

	Per cent.
Quartz (SiO_2)	9·00
Clay ($Al_2Si_2O_7 + 2H_2O$)	20·00
Gypsum ($CaSO_4 . 2H_2O$)	35·00
Hæmatite (Fe_2O_3)	2·00
Dolomite (Ca, Mg) CO_3	34·00
	100·00

The significant points of this analysis are : (i) the small proportion of hæmatite in view of the intensely red colour, and (ii) the presence of calcium and magnesium carbonate in almost the exact proportions of pure dolomite. Heated before the blow-pipe the red marl melts to a nearly colourless glass[4].

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[1] E. H. Pascoe. *Mem.*, XL, 352 (1920).

[2] Included in the " Boulder Beds " on Wynne's map, *Mem.*, XVII, . Pt. 2 (1880).

[3] Private communication.

[4] H. Warth. *Rec.*, XLVII, 78 (1916).

Gee has found the gypsum and dolomite of the lower part of the series in many sections contorted, and sometimes crushed into irregular "pebbles" suggestive of an autoclastic structure. In many cases, these "conglomerates" are obviously the result of tectonic pressure, which has shattered thin intercalations of gypsum within the less competent beds of red clay and marl. Some of the more massive gypsum shows what Gee calls a "gneissic" and Murray Stuart a "schistose" structure. Middlemiss remarks that at every junction between the Salt Marl group and the Purple Sandstone, the layer of rock along the junction is brecciated[1].

The rest of the Saline group is made up of beds and masses of rock-salt, gypsum and subordinate dolomite. The greatest development of salt is at Khewra (Kheura) ; in the Mayo Mine of this area, intercalated in the upper part of the Red Marl are five large beds of salt whose united thickness is not much less than 400 feet, alternating with marl or *kalar*[2] of much the same total thickness. Some of the individual beds of salt are here over 100 feet thick, but elsewhere they average about 20 feet. A very conservative estimate of the reserves of rock-salt in the Mayo Mine, within a distance of 300 feet to the dip, is of the order of four million tons, the equivalent of 67,387,000 cubic feet, but the ultimate total is likely to be far greater[3]. It is marketed without being refined. The salt is pinkish in colour and occurs usually near the upper boundary of the Red Marl, just below the greatest development of gypsum. It frequently shows perfect lamination, and colour-bands from six inches to two feet wide are not uncommon. Potash deposits, consisting of langbeinite ($K_2SO_4.\ 2MgSO_4$), sylvite (KCl) and kainite ($KCl.\ MgSO_4.\ 3H_2O$) are also found, usually interbedded between a seam of rock-salt and one of marl. Other occasional constituents are kieserite ($MgSO_4.\ H_2O$) and glauberite ($Na_2SO_4.\ CaSO_4$). Epsom Salt ($MgSO_4.\ 7H_2O$) commonly crystallises on the surface of the salt marl and *kalar* in the passages of the mines, a phenomenon which would seem to indicate that magnesium salts are of common occurrence in the deposit.

Two seams of potash have been located in the Mayo Mine of Khewra, and one seam in the Nurpur mine[4]. Christie found the potash deposits comparatively constant in thickness and only gradually dying out. A similar conclusion was drawn by the author who found it possible to trace the potash-bearing salt in small anticlinal puckers several feet in amplitude. The principal potash-bearing band in the Mayo Mine, for instance, with an average thickness of six feet and a potash content of 6·8 to 9·6 per cent. has been traced for some 850 feet along the strike and over 250 feet to the dip ; it may well be continuous with an eight foot seam, containing 7·7 per cent. of K_2O and found 700 feet further along its strike[5]. In the Nurpur area, some of the material mined contains as much as 14·1 per cent. of potash, but the total quantity is small[6].

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[1] C. S. Middlemiss. *Rec.*, XXIV, 31 (1891) ; Murray Stuart. *Rec.* L. 77 (1919).

[2] The vernacular term "*kalar*" or "*kallar*" is used for salt or for salt marl too impure to be marketable.

[3] *Gen. Rep. Rec.* LXV, 65 (1931).

[4] *Gen. Rep. Rec.* XLI, 75 (1911)

[5] *Gen. Rep. Rec.* XLIII, 21 (1913).

[6] *Gen. Rep. Rec.* XLVIII, 15 (1917).

Very often, as pointed out by Christie,[1] the potash and magensium deposits which must have been the final and residual products of evaporation, are overlain by a layer of salt marl frequently containing kieserite but consisting chiefly of salt, with calcium sulphate, impalpable ferruginous clay and innumerable quartz grains of variable size and almost all highly angular ; such deposits seem to have afforded local protection from solution to the very soluble salts below when a fresh influx of salt water invaded the salt lake. That the temperature at which the salt was deposited was at least as high as 25°C. locally is indicated by the presence of anhydrite in some of the quartz crystals found in the Salt Marl. According to Van't Hoff, the precipitation together of rock-salt, langbeinite, sylvite, kieserite and kainite is possible only when crystallisation from solution has taken place at about 80°C. At the Sambhar Salt Lake in the Rajputana desert, one of the hottest regions of the world, the maximum temperature during the hottest part of the year reached in the shallow *kyars* by the brine—which, incidentally, contains no potash and only a trace of magnesia—is only 39°C. It is unlikely that this temperature could have been exceeded in the case of the Salt Range deposition, and Christie is inclined to deduce a subsequent depression to some considerable depth. His suggestion is that the salt deposits were laid down at normal surface temperatures and afterwards thermally metamorphosed to their present constitution by depression to a depth of something like 1,800 metres. During the process of depression, and in the presence of enclosed moisture, kainite would have been partly decomposed into sylvite, kieserite and water—

$$KCl.\ MgSO_4.3H_2O = KCl + MgSO_4.\ H_2O + 2H_2O,$$

giving an increase in volume of about nine per cent., while carnallite and kieserite would react to form langbeinite :-

$$3(MgSO_4.\ H_2O) + 2(KCl.\ MgCl_2.\ 6H_2O) = K_2SO_4.\ 2MgSO_4 + 3MgCl_2 + 15\ H_2O.$$

The disappearance of the magnesium chloride remains to be accounted for, but this salt is not entirely absent and is found in appreciable quantities in the overlying marl seams, and sometimes in fissures.

In addition to the secondary gypsum intrinsic to the Salt Marl, extensive beds and masses of primary gypsum are found, usually higher than the salt, but sometimes interstratified with the marl or with the salt ; scattered crystals of iron pyrites, and in several places crystals of bipyramidal quartz, occur in the gypsum. The gypsum itself carries a variable proportion of anhydrite, and the quartz crystals contain inclusions of anhydrite but none of gypsum. Contortion like that seen in the salt is common, and some of the masses have a fragmentary appearance as if broken or dissolved off from a parent mass. Brittle flags of dolomite are associated with the gypsum, and in one or two places contain numerous casts of hopper-shaped crystals of salt ; at Khewra there is a fœtid variety accompanying the pocket of coaly bituminous shales, and occurring close to a trap rock.

The gypsum and dolomite found at the top of the series are irregular in occurrence, but the former in some sections is seen in beds as much as 100 feet thick. The dolomites of these upper horizons are described as usually flaggy, pitted or honey-combed, and sometimes cherty ; associated with them are dolomitic shales. Some of the flaggy dolomites are bituminous and pass locally into low-grade oil shales ; it was in shales of this kind that markings which simulated fossil leaves were found. The upper bands of gypsum and dolomite also show brecciation, contortion and foliation.

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[1] *Gen. Rep. Rec.* XLIV, 260 (1914).

The Khewra Trap, mentioned above, varies from purple to green and purplish grey in colour, and usually includes groups of numerous radiating needles of lighter colour[1]. In all cases the rock, which occurs sporadically in the eastern section of the range, has been much altered and often decomposed into a grey or purplish mud enclosing hard fragments of altered trap. The rock has been described as dioritic, of intermediate composition, and associated with what are said to be tuffs and ashes of paler colour, but it is impossible to deduce the original composition of this rock or to say whether it represents an intrusion, as Dr. Christie thinks probable, or a surface flow. Dr. Gee is more in favour of the latter view, basing his opinion on the constancy of the horizon of the rock over a distance of at least thirty miles. In thickness it varies from a few feet up to a maximum of about 20 feet but, judging from the amount of decomposition products in the Nila Wuhan (Nilawan) gorge, it may have attained an appreciably greater thickness.

Gee divides the Saline series of the eastern half of the Salt Range, where it reaches its greatest development, into the three stages listed above, the upper and middle of which show resemblances, now believed to be fortuitous, to the beds mainly exposed in the Kohat salt region. Of the lower the base is not seen, but probably more than 500 feet are exposed, consisting of marl, gypsum, bituminous shales and dolomite. The middle, where fully developed, comprises at least 750 feet of red marl with thick seams of rocksalt but may be reduced locally to a very thin band of bright red marl, while the upper stage is composed of massive gypsum with flaggy dolomite and some bituminous shales, varying in thickness up to about 200 feet[2]. Near Kussak, the Saline beds are exposed in two well-marked anticlines, the axes of which are formed of the crushed lower stage. To the north of Khewra, the series is believed to be repeated by a fault. In the vicinity of Malot, large outcrops of rocksalt make their appearance within the lower stage. Below Malot and Dandot, the structure is greatly complicated by fold-faulting, overthrusting, incompetency of the strata and subsidence[3]. In and around the Gandhala gorge, the strata are repeated by an overthrust, bringing the Salt Marl and Nummulitic limestone over the Nummulitic limestone and Siwaliks (Kamlials). The north-westward continuation of the faulted Nawabi Kas anticline results in the complicated outcrops of Salt Marl and Purple Sandstone among the Nummulitic strata of the Kalar Kahar plateau[4]. Northwest of Nurpur, in the neighbourhood of Vasnal, the Red Marl is again exposed as a small inlier in the Nummulitic limestone, the structure being that of a sharp faulted, and sheared dome.

The base of the Saline series is nowhere exposed, and no estimate of its total thickness is possible. Wynne records 1,500 feet at Kussak Fort, assuming the stratification of the deposit to be parallel to that of the overlying rocks, but as there is good reason to believe that the Saline series has in most places yielded more to distortion than its less incompetent accompaniments, this figure may be an over-estimate of the thickness exposed in this locality.

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[1] E. R. Gee. Private communication.

[2] E. R. Gee. *Current Science*, 460 (June, 1934).

[3] *Gen. Rep. Rec.*, LXV, 115-117 (1931).

[4] See Note 2 on p. 570.

The association of the Saline series, especially the Red Marl, with others is often complex. Although occurring normally beneath the Purple Sandstone, it is sometimes found in juxtaposition with some of the newest rocks and, as Wynne remarks, "continually makes its appearance among the stratigraphic wreck which it has itself produced"[1]. There is abundant evidence to show that the Saline series includes among its members true sediments.

Before leaving the subject of the Saline series, it will not be out of place to record some of the arguments used from time to time in support of the theory that the series is of Tertiary and not of Cambrian or pre-Cambrian age.

In the first place, both the Salt Range and the Potwar have more in common structurally and stratigraphically, with the Extra-peninsular mountain tracts than they have with the Peninsula. This is not perhaps a relationship of first class importance, but the fact remains that the Cambrian and pre-Cambrian in the neighbouring Extra-peninsular areas of Kashmir and Spiti are entirely unaccompanied by salt deposits; the only Extra-peninsular salt deposits, those of Mandi, are usually accepted as Tertiary. The tight folding around Chharat-Khair-i-Murat is more typical of the Extra-peninsular folding west of the Indus, and is a result of the Himalayan movement; the gentler flexuring found between these steep structures and the Salt Range scarp was at one time explained as due to the easy riding of a *nappé* over the lubricant salt. It is explicable also on the assumption that the Himalayan compression has here been distributed over a wider section; in any case, the aggregate inclination of the beds in the Potwar is no gentler than it is in some of the Himalayan *duns*. The Salt Range itself is not without evidence of marked disturbance, inversion and thrusting. Furthermore, the close geographical association of two salt deposits of supposedly immense difference in age seems a remarkable though not impossible coincidence. This coincidence is enhanced by the fact that both salt deposits carry indications of petroleum, a mineral known to be indigenous to the early Tertiary of northwest India. The effect of this double coincidence would be accumulative were it not that petroleum indications are almost invariably accompanied by the presence of salt; the conditions necessary to produce the deposition of rocksalt appear, in fact, to be those which favour the formation of petroleum from organic material.

It has been suggested that the presence of oilshale intercalations within the Saline series, especially when near the top of the formation, sufficiently unmetamorphosed to yield volatile hydrocarbons in sufficient quantities to permit of their ignition, is opposed to the supposition of an immense low-angle thrust along the upper limit of the series, and that the volatiles would probably have been driven off by such a compressional disturbance and the original oilshale metamorphosed to petroleum-free carbonaceous shales or even to more highly altered graphitic shales. It might, however, be argued with equal cogency that such metamorphic changes would have been brought about by age, and that it is the survival from Cambrian or pre-Cambrian times of such fresh petroliferous shales that needs explanation[2].

Two or three additional arguments advanced by Mr. R. van V. Anderson in support of a Tertiary age for the Saline series are: (i) the young appearance of the carbonaceous and other shales associated with the salt and gypsum, as compared with the induration, moderate though it is, which has affected the Palæozoic strata of the range ; (ii) the close lithological resemblance between the calcareous and siliceous shales of the Saline series and the fossil-bearing shales of the Nummulitic series ; and (iii) the thrusting of what is claimed to be the Purple Sandstone over Siwalik beds near Jalalpur[1].

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[1] *Mem.*, XIV, 72 (1878).

[2] *Abst. Proc. Geol. Soc. Lond.*, No. 1442, 7th June, 1948, p. 82.

At three localities carbonised plant fragments have been found in beds which were regarded as being *in situ* in the Saline series[2] ; the authenticity of these occurrences has been questioned, but at one of the localities, the Kalra Wahan, some red clay, thought to occur indigenously within the red Salt Marl, yielded not only carbonised stem fragments but also several small leaves of apparently dicotyledonous type[3]. The inference made was that the Saline series included both Ranikot (Palæocene) and Laki (Lower Eocene) beds, a conclusion to which the frequently bituminous character of the deposits lent some support.

Another of the arguments in favour of a Tertiary age for the Saline series was based on a section in the western end of the range. Four miles east of Daud Khel, it was claimed that the foraminiferal Eocene limestones (probably of Laki age) at the top of the local Eocene sequence along the northern dip slopes of the range, pass laterally into the upper of the three Saline stages. This passage from the grey and white limestones of undoubted Eocene age into dark fœtid limestone with subordinate gypsum, and the more rapid passage of the latter into massive gypsum some 300 feet thick, was said to take place clearly within a few yards either by metasomatic replacement or by ordinary lateral, change in the nature of the deposited sediments[4]. Above the limestones and the gypsum, the Lower Siwalik beds were said to succeed regularly, whilst below the limestone-gypsum facies of this passage could be recognised the middle and lower portions of the normal Nummulitic sequence cropping out with equal regularity. About three quarters of a mile northwest of the end of these exposures, the massive gypsum is underlain by typical red marl with rocksalt, which, therefore, appears to take the place of the light grey shales and limestones of the middle portion of the Nummulitic sequence. The basal part of the latter, in the form of nodular, foraminiferal limestones, is found adjacent to the gypsum and salt marl and underlying them. The salt marl and gypsum are associated with the Talchir Boulder Bed in the same way as they are in the neighbouring scarps.

The impression, therefore, was that Palæozoic and Mesozoic strata, of which a more or less representative geological record from Lower Cambrian to the base of the Eocene can be seen condensed within 1,000 feet of the Salt Range cliffs had been thrust southwards over the Saline beds. The first to put forward the suggestion of such an overthrust seems to have been Dr. Noetling[5]. It was thought that deposits such as salt marl and gypsum would respond to a compressional force in much the same way as would a highly viscous liquid, the harder rocks riding undisturbed for the most part over these plastic and yielding materials.

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[1] *Bull. Geol. Soc. Amer.*, Vol. XXXVIII, 672 (1927).

[2] *Gen. Rep. Rec.*, LXVII, 22 (1933).

[3] *Gen. Rep. Rec.*, LXIX, 23 (1935).

[4] *Gen. Rep. Rec.*, LXIX, 63 (1935).

[5] *Gen. Rep.* 1902-03, p. 26.

Evidence of such overthrust seemed to be present in the brecciation and slickensiding noticed frequently in the Purple Sandstone near its junction with the gypsum. According to Mr. R. van V. Anderson, the lower 20 feet or so of the Purple Sandstone show signs of disturbance which increases progressively downwards, the basal 50 to 100 feet being described as a zone of severe shattering ; the persistent character of the sandstone, in spite of its brecciation, was at the same time admitted[1]. The superposition of the Purple Sandstone upon the Salt Marl is, however, not invariable and the latter appears locally to have been overridden by higher members of the Salt Range sequence. Where the basal part of the supposed *nappé* or overthrust column is the Talchir Boulder Bed, such signs of overthrusting were said to be still more noticeable ; numerous sections show that, throughout a thickness ranging up to about 20 feet above the junction with the Saline beds, the stratification of the shaly matrix has been obliterated, while the majority of the boulders, consisting as they do of hard granite, gneiss, quartzite, rhyolite, etc., have been crushed and sheared. Where the Boulder Bed rests on early Palæozoic or pre-Cambrian strata, as it does in the eastern and middle parts of the range, there is no evidence of such relative movement.

The three or four inliers or " oases " of bright red marl in the tract of Nummulitic limestone of the plateau margin at Ainwan, Kalar Kahar, Vasnal and Kalabagh lie along lines of cross or oblique faulting and appeared to belong more likely to the supposed *nappé* than to the overridden sequence. It would, in fact, have been strange if none of the Saline series had been carried along as part of the *nappé*, and it is easy to understand how readily such soft material might have been brought to the surface up some of the cross fractures which, it was supposed, accompanied the thrust. The Salt Marl outcrops at Vasnal and northeast of Choa Saidan Shah are overlain by the Purple Sandstone[2].

The composition of the Talchir Boulder Bed also appeared to furnish negative evidence against the view that the Salt Marl was in existence in Upper Carboniferous times when the accumulation of the boulders took place. It had been generally noted that no trace of the Marl, a conspicuous and brightly coloured bed, could be found in the Boulder Bed, whether in the form of included fragments or as a coloration of the matrix ; it was at the same time admitted that neither did the Boulder Bed include fragments of the Purple Sandstone or of the overlying beds which contain the Cambrian fossils and which must have been in existence at the time the Boulder Bed was deposited. Very recently, Dr. Gee reports having found definite relics of the Salt Marl as well as of the dolomite beds in the Talchir Boulder Bed ; this will be referred to later.

A second argument of a still more negative character than the last is based upon the condition of certain fragments of dolomite included in the Salt Marl. These fragments are pitted, corroded and honey-combed and, in a section of the

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[1] *Bull. Geol. Soc. Amer.*, Vol. XXXVIII, 671 (1927).

[2] Gee states that the Salt Marl outcrops of Vasnal are associated with the Purple Sandstone and other Palæozoic beds, though the structure is faulted. He reports that the Ainwan exposures underlie Talchir conglomerates, and that the Salt Marl at Kalar Kahar has been 'intruded' upwards along a fault and is now bounded on the one side by Eocene and on the other by Siwalik deposits. The Saline series of Kalabagh occurs in an area of very complicated tectonics and he regards the occurrence as an irregular dome in which considerable movement of the rock-salt has occurred. In all these cases, he considers that the marl and rock-salt are homotaxial with that of the Salt Range scarp and Lower Cambrian or pre-Cambrian in age.

Sirakka (Kawadh) gorge, are described as showing an ultimate passage into the red marl. Two miles north of Bari Khel, where the Salt Marl is immediately overlain by the Talchir glacial Boulder Bed, the former contains numerous large aggregates of a hard, compact dolomite, whose peripheral portions are also pitted or honey-combed, the cavities being filled with gypsum, and only the central portions remaining unaltered. It might be expected, therefore, that, were the Salt Marl and its dolomite contents older than the Boulder Bed, some of the numerous dolomite pebbles in the latter would show traces of pitting or corrosion. That none of them has been cited in support of the conclusion that the corrosion of the dolomite in the Marl was of later date than the deposition of the Boulder Bed. In estimating the precise value of this piece of evidence, it must be remembered, firstly, that the corrosion of the dolomite in the Marl, if it were effected by meteoric waters after the accumulation of the Boulder Bed, does not necessarily mean that the deposition of the Salt Marl and its included dolomite was also subsequent to that of the Boulder Bed; secondly, that some of the dolomite pebbles in the Boulder Bed may have been derived from the Magnesian Sandstone, a deposit of early Palæozoic age; and lastly, that on account of the *quasi*-liquid character of the salt and Salt Marl, any harder inclusions therein are necessarily suspect, and may have broken off from any adjacent bed and become involved in the plastic marl or salt as a kind of autoclastic xenolith[1].

Recently from thin parallel bands of Salt Marl interstratified apparently with the salt at Khewra, Professor B. Sahni and Mr. B. S. Trivedi have obtained numerous fragments of angiospermous wood, some gymnosperm tracheids with large round bordered pits, and at least one well-preserved, winged six-legged insect with compound eyes; if the indigenous character of the marl bands and their contents be accepted, their age and that of the accompanying salt could not be as old as Cambrian or pre-Cambrian[2]. The contamination of the marl bands with these vegetable fragments is described as not of a casual kind, and the latter have been found in samples of oil shale and dolomite belonging to the Saline series. At the same time, the organic fragments are all minute and indistinguishable from modern vegetable refuse, and to what extent they could be introduced into an ancient formation by percolating waters remains for further work to decide. Dr. Gee notes that even the shales and dolomites may have been impregnated in this way, for it is difficult to obtain even small specimens of these rocks which on being hammered, do not fracture along an obscure cleavage, on the joint-planes of which extraneous matter, evidently introduced by percolating solutions, can be observed. Check observations on similar rock material of unquestionable Palæozoic age may do much to clear up this point.

Such are some of the considerations which have caused a certain amount of dissatisfaction with the original conclusions of Wynne. During the final stage of his resurvey, however, Dr. Gee discovered sections which leave no doubt in his mind as to the Cambrian or pre-Cambrian age of the Saline series. On the southern slopes of the Sakesar ridge, in the middle-western part of the range, he reports definite evidence of a normal stratigraphical though unconformable junction between the basal Talchirs and the underlying Saline series. Here the Saline series comprises the three stages mentioned above—a lower gypsum-dolomite stage, a relatively thin middle stage of red salt marl with very occasional beds of rocksalt, and a top stage of dolomite with some gypsum. The Talchirs include thick, dark-coloured tillites, often of a dull purple colour near the base. These argillaceous tillites contain numerous pebbles and boulders of granite, quartzite, and other rocks including dolomite. In places, they rest on the top dolomite stage of the Saline series, but laterally they transgress on to the red salt marl. In one locality, boulders of the basal Talchirs appear to have become embedded in the uneven surface of the dolomite. The boulders here show no sign of shearing, and the contact appears to be a sedimentary one. At an adjoining locality, the dolomite, here reduced to a thickness of a few feet, can be seen capped by undisturbed Talchirs whose basal bed is composed largely of angular and subangular fragments of dolomite derived apparently from the top stage of the Saline series of the vicinity. Where the Talchirs transgress on to the red salt marl, excavation of the junction showed that, while shearing had occurred in some cases, in others the contact was a normal sedimentary one, the basal purplish Talchir beds containing fragments of red shaly marl and some pebbles of grey dolomite and very occasionally of gypsum. In the more northwesterly part of the range, Gee found decided evidence of shearing in numerous cases along this junction[1].

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[1] As an example of the plasticity of these deposits may be mentioned the discovery of what was at first reported to be a piece of fossil wood in the salt of one of the mines; on careful examination this was shown to be an old mine prop which had become engulfed in the salt.

[2] Abst. Joint Meeting, *Ind. Acad. Sci. & Nat. Acad. Sci.*, at Hyderabad, December 1943, pp. 25-26; see also: "Nature", Vol. 153, April 15, p. 462 (1944); and *Proc. Nat. Acad. Sci. Ind.*, Vol. XIV, Sec. B; pp. i-xxvii and 49-66 (1944).

In support of the older age of the salt and Salt Marl, the following arguments have been urged at one time or another : (i) the constancy with which the Purple Sandstone overlies the Saline series ; (ii) the absence of *Nummulites* in beds belonging to the Saline sequence ; (iii) the apparently undisturbed state of so much of the Salt Range column of deposits ; (iv) the presence among the fossiliferous Cambrian beds of a salt-pseudomorph zone, proving that salt-forming conditions existed during that period ; (v) the difference in tint between the reddish salt of the Salt Range and the grey salt of Kohat ; and (vi) the Cambrian age now claimed for the Hormuz salt-bearing series of southwestern Persia. With regard to (v) both grey and red salt are present at Nandrakka, a locality intermediate in geographical position between the Kohat and Punjab salt regions. Red salt, though exceedingly rare, is not entirely absent in the Kohat region[2]. No seams of potash salt occur in the Kohat region, but potash and magnesium have been detected in the water dripping from the salt at Nandrakka and at Kalabagh. The absence of *Nummulites* and other forms of animal life from the Saline formation can scarcely be attributable to the salinity of the waters, unless this salinity was in excess of that which prevailed during the Kohat deposition in which *Nummulites* and molluscs managed to exist. The age of the Hormuz formation was at first thought by Dr. Pilgrim, who originated the term, to be " Upper Cretaceous or Lower Eocene"[3]. Later on he expressed the opinion that the whole series might be Jurassic with the chance that the basal rocksalt stage might be Triassic and the purple sandstones and volcanic beds at the top Lower Cretaceous[4]. The general consensus of opinion among the Anglo-Iranian Oil Company's geological staff is that the

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[1] Private communication.

[2] Murray Stuart. *Rec.*, L, 29 (1919).

[3] *Mem.*, XXXIV, Pt. 4, 7 (1908).

[4] *Mem.*, XLVIII, Pt. 2, 19-24 (1925).

Hormuz series, where it is a definite sequence and not a chance assemblage of jumbled fragments, is of Cambrian age; many of the Persian salt plugs would be difficult to explain on any other supposition.

Gee finds that the Salt Marl outcrops of Vasnal are associated with the Purple Sandstone and other Palæozoic beds, though the structure is faulted. He reports that the Ainwan exposures underlie Talchir conglomerates, and that the Salt Marl at Kalar Kahar has been "intruded" upwards along a fault and is now bounded on one side by Eocene and on the other by Siwalik deposits. The Saline series of Kalabagh occurs in an area of very complicated tectonics and the occurrence is regarded as an irregular dome in which considerable upward movement of the rocksalt has taken place. In all these cases, Gee considers that the marl and rocksalt are homotaxial with that of the Salt Range scarp, and Lower Cambrian or pre-Cambrian in age[1].

Jhelum series.—With two interesting exceptions, exposures of the Jhelum series are confined to the eastern part of the range; overlain by younger beds, the various stages of this formation thin out successively in a westward direction by denudation, one after the other becoming the uppermost present. The unconformity, as noticed by Gee, is not quite of the regularly graduated nature it was at first supposed to be, but in a general way there is a transgression westwards of the Upper Carboniferous Boulder Bed on to older and older stages of the Jhelum series, in spite of interruptions in at least two places[2]. To the west of the Sardahi (Sardi) gorge, for instance, the Magnesian Sandstone diminishes in thickness and eventually dies out near the Nila Wahan ravine[3]. A dozen miles further west, it is the turn of the Neobolus Shales to disappear, which they do in the vicinity of Katha, bringing the overlying Talchir Boulder Bed into direct contact with the Purple Sandstone. The Purple Sandstone is repeated by overthrusting at various places along the range; such repetition can be seen, for example, in the exit of the Dilliwali gorge north of Nali, and again to the north of Kund and Sikriala. This sandstone is absent in many sections, especially between Warcha and Chhidru; in the western end of the range, the Upper Carboniferous Boulder Bed overlies the Saline series. Gee also found in several of the gorges evidence of similar transgression towards the north. The axial beds of the Mount Chel monocline comprise the upper part of the Purple Sandstone and the Neobolus Shales, affected by small cross-faults[4].

The break between the Purple Sandstone and the Neobolus Shales, though unaccompanied by any visible discordance, is described by Gee as clean and well defined. The boundaries between the other stages are in most places clearly distinguishable, except in the middle portions of the range where the Magnesian Sandstone beds are less massive and appear to pass down into the Neobolus Shales; a similar transition between these two stages is seen in the inliers of Chittidil and Chhidru, in the west.

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[1] An alternative suggestion has been made that the Ainwan "Oasis" is made up of Lower Chharat (Middle Eocene) strata, and that the inliers at Kalar Kahar, Mari, Kalabagh, and to the north of Kalabagh, may also belong to the Eocene sequence of Kohat.

[2] *Rec.*, LXVIII, 116 (1934).

[3] *Gen. Rep. Rec.*, LXVI, 115 (1932).

[4] *Gen. Rep. Rec.*, LXIII, 132-138 (1930).

The later beds of the Jhelum series were laid down under conditions of aridity which are especially indicated by the Salt Pseudomorph beds. A shallow sea is to be visualised, with deeper-water conditions during the Neobolus Shale epoch; the Baghanwala stage or "Salt Pseudomorph Zone" was deposited probably in a very limited estuarine basin.

Isolated occurrences at Chittidil and Chhidru.—As already noticed, the Jhelum succession is largely absent in the western parts of the Salt Range, but there are two important local developments of such rocks. One of them is at Chittidil, on the western bank of the Dhodha Wahan near its exit south of the Sakesar ridge. Here the Purple Sandstone is present in force and is succeeded by over 100 feet of grey and purplish shales and dolomitic sandstones, which appear to represent the Neobolus Shales and Magnesian Sandstone; above the latter is a thick sequence of the Salt Pseudomorph beds. The other locality is the Khansaman gorge near Chhidru, further west. Here the Talchir Boulder Bed lies with marked unconformity upon the following sequence in descending order: 145 feet of the Salt Pseudomorph beds; 85 to 99 feet of Magnesian Sandstone beds; 105 feet of the Neobolus Shales; and about 350 feet of the Purple Sandstone series.

The Purple Sandstone.—The Purple Sandstone, though very regular and constant in the eastern part of the escarpment, where it generally forms the first cliff rising out of the talus and broken ground, varies in thickness from 200 to 450 feet, and has been identified as far west as Chhidru but not beyond in the cis-Indus range; on the other side of the river, a local occurrence is recorded by Gee near Saiduwali, at the foot of the Kingriali scarp of the Khasor hills, south of the Kurram river. In the eastern portion of the cis-Indus range, it is exposed in the Diljaba and Karangal ridges, as well as in the inliers of Vasnal, at distances of about 16 and 12 miles respectively from the base of the scarp; when traced westwards in the latter, it becomes thinner and thinner and in some sections reduced to 20 or 30 feet of maroon shales and flags separating the Saline series from the Talchirs.

The Purple Sandstone is a deposit of marked uniformity in aspect and texture[1]. It consists invariably of a basal 20 or 100 feet of maroon shales with bands of fine, even-grained flagstones, passing up into more massive, maroon or occasionally buff-coloured, jointed sandstones with thin bands of clay. The maximum thickness of this upper portion is about 300 feet, and the colour of its sandstones becomes paler towards the top. The basal earthy beds, which in the great majority of sections are found immediately overlying the Saline series, appeared to Wynne to be a transition between the latter and the harder sandstones above, these harder sandstones are described as being of a hardness "considerably less than that which is usual in Palæozoic rocks". Both carbonate of lime and carbonate of magnesia are present in the sandstones, which are regularly bedded, usually fine-grained and often exhibit excellent ripple-marks. Irregular "fucoid" impressions are observable among the lower flags but may be of inorganic rather than organic origin. There are points of resemblance, of which the presence of ripple-marks is one, between the Purple Sandstone and sandstones of the Upper

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[1] A. B. Wynne. *Mem.*, XIV, 84-87 (1878).

Vindhyan such as the Kaimur and Bhander[1]; it is quite possible that the Purple Sandstone belongs rather to the preceding chapter than to this. On the south-east slopes of the Jogi Tilla ridge, there is in the middle of the Purple Sandstone series a local development of grit and conglomerate, the angular or moderately rounded pebbles of the latter consisting of grey and red quartzite and limestone, with included pieces of dark red shale and sandstone resembling the subjacent flaggy beds[2].

The Purple Sandstone has been described by one observer as passing up gradually into the overlying Kussak stage, but as the latter is stated in the same paper to be " always well and sharply defined," there is considerable doubt about the passage[3]. Most observers refer to the Kussak stage as lying abruptly upon the Purple Sandstone, though usually with the appearance of conformity, and Gee describes the Neobolus Shales as very distinct in lithology from the Purple Sandstone. The rest of the sequence, from Neobolus Shales up to the Salt Pseudomorph beds, is conformable. In the east, the three upper stages can be distinguished by lithological characters alone, but in the Dhodha Wahan and Chhidru areas this distinction is less marked and the succession appears to be one of continuous sedimentation, a deduction borne out by fossil evidence[4].

Kussak stage.—The Kussak (Khusak) stage or Neobolus Shales stage occurs in the same regular manner in the eastern Salt Range, and consists of dark shales associated with sandy and calcareous beds, the thickness varying usually from 120 to 160 feet, though sometimes exceeding the latter figure. Here they form a prominent, easily recognised band on an inclined terrace between cliffs of the massive Purple Sandstone and cliffs of the Magnesian Sandstone. The base is nearly always a pebble-bed, while the topmost horizons appear to pass up gradually into the Magnesian Sandstone stage. In the vicinity of Katha, the Kussak stage is reduced to 30 feet of purplish-grey shales and thin sandstones with a basal pebble-bed like that in the east; a few miles further west, the main outcrop dies out but recurrences are seen locally at Chittidil, S.S.W. of Sakesar and near Chhidru. In the east, the Neobolus Shales also occur in the Karangal and Diljaba ridges but not at Vasnal where the Talchirs rest directly upon the Purple Sandstone. The Kussak stage is of extreme interest on account of its contained fossils.

The bottom bed of the Kussaks, forming a very regular and characteristic horizon, is a distinctive grit and conglomerate not more than a foot thick. The conglomerate consists of a matrix of well-rounded, medium to coarse, sand grains of yellowish brown colour, in which are embedded rounded pebbles of white and yellow quartzite and smooth, flat, oval, pebbles, the largest of them several inches in diameter, of dark grey-green and black slate and dark semi-quartzite. Above come sandy micaceous shales and soft, micaceous, glauconitic sandstones of grey or grey-green colour, including near the base several thin bands of purple sandstone. Higher up, the sandstones and sandy shales, with annelid casts, become prominent and include two or three bands of dark purple-grey clay shales, each several feet thick ; it is from beds of this type that the Kussak fossils come. In this upper half of the stage are bands of flaggy, light grey sandstone, which is calcareous, often dolomitic, and sometimes glauconitic. These bands are hard and jointed and closely resemble certain of the Magnesian Sandstone beds ; they form a kind of passage into the latter, and there is no break in sedimentation.

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[1] J. B. Auden. *Mem.*, LXII, 247 (1933).

[2] E. R. Gee. Private communication.

[3] F. Noetling. *Rec.*, XXVII, 75 (1894).

[4] E. R. Gee. *Rec.*, LXVIII, 119-120 (1934). The close relationship between the Purple Sandstone and the Saline series induced the author to suggest that the two formed part of the same Tertiary sequence. This suggestion appeared to derive support from the soft and friable nature of many of the registered specimens of the Purple Sandstone which are indistinguishable from characteristic Eocene beds; it is, however, probable that there has in the past been some confusion, in collecting from complicated structures, between true Tertiary silts and a much older Purple Sandstone. Dr. Gee failed to find any evidence of a thrust-plane separating the true Purple Sandstone from the overlying Neobolus Shales, and speaks of the junction as being extremely regular throughout the scarp. The Purple Sandstone had been noticed underlying as well as overlying the Marl, and the latter had been described as in places passing up into the sandstone; the two deposits had also been recorded as interbedded with each other in two or three places.

Fossils are said to have come from two horizons, one near the base from a shale band containing *Neobolus*, the brachiopod which has given its name to the stage, and the other close to the top, immediately below the Magnesian Sandstone. From the lower horizon come [1]:

Annelid tracks ;
Hyolithes sp.[2] ;
Neobolus warthi Waag. (abundant) ;
Discinolepis granulata Waag. ;
Schizopholis rugosa Waag. ;
Lingulella khurensis Waag.[3] ;

From the upper horizon the following have been identified :

Annelid tracks ;
Hyolithes wynnei Waag. ;
Ptychoparia warthi (Waag.)[4] ;
Wynnia warthi Walc.[5];
Redlichia nœtlingi, var. *angulata* (Redlich)[6] ;
,, ,, var. *lata* (Redlich) ;
Lingulella wanniecki Redlich[7] ;
,, *fuchsi* Redlich ;
Acrothele (*Redlichella*) *granulata* (Linnarsson)[8] ;
Botsfordia granulata (Redlich)[9].

Jutana stage.—The Kussak stage is succeeded by the Jutana dolomites or Magnesian Sandstone stage. The lower parts of this consist of cream-coloured or white, massive, sandy dolomite with intercalated beds of clay, and are characterised by the cryptic *Pseudotheca waageni* Redlich—formerly described as *Stenotheca rugosa* Walc., var. *aspera* Walc.—and *Ptychoparia richteri* Redlich ; these beds pass up into hard clay with *Lingulella fuchsi* and possibly *L. wanniecki*[10].

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[1] W. Waagen. *Pal. Ind.*, Ser. XIII, Vol. IV (1889-1891) ; K. Redlich. *Ibid.*, New Ser., Vol. I, Mem. 1 (1899).

[2] Waagen's *Neobolus wynnei*, *Lakhmina linguloides*, and *L. squama*, were all found by Walcott to be specifically indistinguishable from *Neobolus warthi*. The same observer has shown that Waagen's "*Lingula warthi*" is in reality but the ventral valve of *Lingulella khurensis*.

[3] Formerly "*Lingula khurensis*."

[4] In Korea and Southern Manchuria the zone of *Ptychoparia* occurs above the four *Redlichia* zones.

[5] Formerly "*Orthis warthi*"; see C. D. Walcott. *U. S. Geol. Surv. Monogr.*, LI, 771 (1912).

[6] Formerly referred to as *Hoeferia noetlingi* ; see C. D. Walcott. *Proc. U. S. Nat. Mus.*, XXIX, 24 (1905). *R. noetlingi* is closely related to and not easily distinguishable from *R. chinensis* Walc., *R. nobilis* Walc. and *R. finalis* Walc.

[7] Identified by C. D. Walcott.

[8] Waagen's "*Orthis warthi*"; see C. D. Walcott. *U. S. Geol. Surv. Monogr.* LI, 771 (1912).

[9] Called by K. Redlich, *Mobergia granulata* (*Pal. Ind.*, New Ser., Vol. 1, *Mem.* No. 1 (1899); see C. D. Walcott, *U. S. Geol. Surv. Monogr.*, LI, 605 (1912).

[10] C. D. Walcott. *U. S. Geol. Surv. Monogr.*, LI, 502 (1912).

Associated with the dolomites of the lower part of the stage are beds of light-coloured, fine-grained, calcareous sandstone and occasional pisolitic or flaggy bands; some of the latter are covered with so-called "fucoid" markings[1], and are separated from each other by greenish or dark-coloured shales. Higher up, the massive dolomites include brecciated types, the matrix and fragments consisting of much the same rock. The magnesian sandstones, which are well jointed, provide a building stone of good quality much used for that purpose as well as for ballast.

The Jutana stage is well developed in the eastern part of the Salt Range, where the thick beds of sandy dolomite resist disintegration and give rise to lofty bold cliffs. It is exposed in the Karangal, Diljaba, Chambal and Jogi Tilla ridges, as well as in the Mount Chel area. Its maximum thickness in the eastern half of the range is over 300 feet, but it dies out earlier than the underlying Kussak stage when traced westwards, its conspicuous scarp disappearing at the same time. In the eastern part of the range, it is succeeded by the Salt Pseudomorph stage except in the Chambal ridge where it is overlain by Miocene beds. West of Khewra, it is overlain unconformably by Talchir conglomerates, and in the western slopes of the Nila Wahan ravine it dies out. In these westerly outcrops and in the isolated occurrences of Chittidil and Chhidru, the dolomitic sandstones are less massive, and bands of softer sandstone and sandy shale become more prominent and contain a few inclusions of gypsum[2]. From the vicinity of Chittidil, Professor W. B. R. King has determined two new species of *Ptychoparia*—*P. sakesarensis* and *P. geei*, a new form of trilobite—*Chittidilla plana*, as well as *Lingulella wanniecki* Redl. and *Botsfordia* (*Mobergia*) *granulata* (Redl.)[3].

Baghanwala stage.—Closely connected with and succeeding the above is the Baghanwala stage, often referred to as the "Salt Pseudomorph zone" consisting of shales or clays with intercalations of thin-bedded flaggy sandstone. The flags, which are prominent in the lower half of the stage, are pinkish grey or less frequently blue-green, often perfectly ripple-marked and sometimes sun-cracked. The shales are characterised by their blood-red colour and by the numerous pseudomorph casts of salt crystals which cover the bedding surfaces. These casts are found indenting the lower surface of the separate flags, and there can be no doubt that they are the result of the crystallisation of salt by the evaporation of salt water and the subsequent covering of the crystals by fresh sediment which, adapting itself to their angularities, preserved their form in the casts now seen. As might be expected, these beds are unfossiliferous, the only possible organic remains found being obscure "fucoid" impressions and worm tracks. Although the thickness may be locally considerable, the extent of this stage is very limited, its variations being due to pre-Talchir erosion rather than to actual differences in the amount of deposition.

East of Baghanwala as far as Jalalpur, the Magnesian Sandstone, instead of the Nummulitic Limestone, caps the scarp, and the Salt Pseudomorph beds crop out along the uppermost dip slopes. The latter beds are absent in the Chambal ridge but recur in the Jogi Tilla area and are present as a thin zone further west in the Diljaba and Karangal ridges and Mount Chel. To the northeast of Baghanwala, the thickness reaches a maximum of 300 or possibly 350 feet, and a similar thickness is seen northeast of Khewra ; in the Khewra gorge, however, the beds are in places reduced to 60 feet or are entirely absent. The main outcrop dies out a few miles west of Makrach, but there are two important local recurrences at Chittidil and Chhidru ; in the former some 330 feet of the beds are present, in the latter the thickness is much less. In the east, there is a rapid passage upwards from the Magnesian Sandstone stage into the Salt Pseudomorph beds ; between the latter and the superjacent Upper Carboniferous Boulder Bed (" Olive series ") is a marked unconformity which, however, is not always apparent in local sections, but which is well seen on the Khewra-Pidh road.

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[1] A. B. Wynne. *Mem.* XIV, 88 (1878); E Vredenburg. *Rec.*, XXXVI, 250 (1908).

[2] E. R. Gee; Private communication.

[3] *Rec.*, LXXV, *Prof. paper* 9, 10-14 (1940).

Faunal relationships.—With regard to the fauna of the Salt Range Cambrian, the first thing to be remarked is that, without exception, all species, at the time of their discovery, were new and had not been up till then found elsewhere in the world. The genus, *Redlichia*, was at first described as *Olenellus*, of which it is a direct descendant, and from which it is distinguished by the presence of a well-developed facial suture and by the distinct separation of the eyes from the glabella. The *Redlichia* fauna has since been discovered in several parts of southern and eastern Asia[1], including, besides the Salt Range and the Himalaya, Mesopotamia, southwest and central Persia, Yunnan, Shan-tung, Shan-si, Chih-li, north Korea and south Manchuria ; it has also been found in western and southern Australia. Opinions vary as to the correct stratigraphical position of this fauna, some observers referring it to the base of the Middle and others to the top of the Lower Cambrian. The Lower Cambrian genus, *Protolenus*, and the Middle Cambrian genera, *Paradoxides*, *Metatoxides* and *Zacanthoides*, stand very close to *Redlichia*, and the latter may be looked upon as an interesting link between the Lower Cambrian Mesonacidae (Olenellidae) and the Middle Cambrian *Paradoxides*. The so-called *Olenellus gilberti* Walcott from the Lower Cambrian of North America is very close to the genus *Redlichia*, but has more the appearance of a transitional form between *Olenellus* and *Redlichia*. Beds with *Protolenus* have been found by Saito below, and beds with *Ptychoparia* above, the Redlichia Shales of north Korea[2], while in Persia, *Redlichia chinensis*, a form difficultly distinguishable from *R. noetlingi*, is associated with some of the Chinese Middle Cambrian trilobites. It is true that most observers have placed the *Redlichia* fauna at the top of the Lower Cambrian and this is where Saito tentatively places the *Redlichia* horizons of Korea but, as Professor W. B. R. King observes[3], they occur above the *Protolenus* horizon and are separated therefrom by a quartzite bed over 80 feet thick. They would appear to fit as well, if not better, therefore, into the base of the Middle Cambrian. *Redlichia chinensis* is the lowest of the four *Redlichia* zones of north Korea and south Manchuria[4].

With regard to the other members of the Salt Range fauna, the nearest ally to *Ptychoparia richteri* is the Canadian *Pt. linnarssoni* Broeg., var. *alata*. *Ptychoparia warthi* (formerly " *Conocephalites warthi* ") has a very close resemblance to *Solenopleura cristata* Linn. from the Paradoxides Beds of Sweden. Regarding the trilobite fragment originally termed "*Olenus indicus*", there is grave doubt as to its generic identity, as well as to the horizon and locality from which it was obtained; its occurrence would be surprising since this genus in the western American life province, to which the Punjab beds would appear to belong, is entirely replaced by *Dicellocephalus*[1]. In the same beds was collected the supposed second species of *Hyolithes* known as *Hyolithes kussakensis* Waag. In the black shales of the *Redlichia* zone, the brachiopods, *Hyolithes wynnei* and *Lingulella wanniecki*, occur in extraordinary profusion. *Botsfordia* is a genus of brachiopods intermediate in character between *Obolella* and *Aerothele*; a species comparable with *Botsfordia granulata* is found in the Upper Redlichia Shales (Lower Cambrian) and the Ptychoparia Beds (Middle Cambrian) of northwest Korea. *Acrothele granulata*, identified by Walcott, is described as very similar to *A. rara* Walc. from the Middle Cambrian of Shan-tung, China, and as intermediate in character between *A. cornacea* Linn. and *Botsfordia granulata* (Redl.)[2]. *Lingulella fuchsi* may be identical with the *Lingulella* sp. described by Linnarsson from the Paradoxides Beds of the Swedish Cambrian. *Pseudotheca waageni* was originally described as *Stenotheca rugosa*, var. *aspera*, but since the organism consists apparently of two valves often united to each other, it must be referred to some other class of the animal kingdom, possibly to the hingeless Lamellibranchiata; its resemblance to the peculiar mollusc *Stenotheca* Salter, from the Lower Cambrian rocks of America, is, however, not to be denied. Another feature of the Salt Range fauna is the abundance of individuals and the paucity of genera and species[3].

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[1] W. B. R. King. *Geol. Mag.*, LXVII, 316-326 (1930).

[2] *Jap. Journ. Geol. & Geogr.*, X, 145 (1933).

[3] *Pal. Ind.*, New Ser., Vol. XXII, *Mem.* No. 5, 5 (1937).

[4] K. Saito, *Jap. Journ. Geol. & Geogr.*, XI, 211-235 (1934).

TRANS-INDUS CONTINUATION OF THE SALT RANGE.

On the other side of the Indus, the Saline series is well represented at Kalabagh, and the Jhelum series is to be seen near the southwestern end of the Khasor hills.

The little town of Kalabagh, much of which is built of pink marl, is situated on the Indus at the southern end of a N.N.W.—S.S.E. ridge rising in places 2,000 feet above the river level. The rock outcrops, which are obviously continuous with those on the opposite bank of the Indus immediately west of Mari, show great complexity, contortion and repetition by faulting. The Saline series, probably several hundred feet in thickness, crops out in a horse-shoe around the base of the end of the ridge and is the lowest formation exposed. Its lowest limit is not seen. Its upper limit is a surface of great discordance—probably a thrust-plane—the folded rocks immediately above varying from Permian limestone to Triassic, Jurassic or Tertiary. The Saline series of this locality includes beds of salt and red salt marl, irregular bands of white gypsum, dark purple or grey shales or hard clays, dark or light flaggy dolomite bands, and a granular quartzitic grit. The salt, found mostly on the eastern and southern sides of the spur, occurs in seams from four to twenty feet thick, and is worked in open quarries or small drifts; the mineral is frequently found in beautiful transparent cubes measuring several inches along the side. Most of the salt is white or pinkish but grey bands also occur, especially in what are believed to be the higher horizons[1]. The Purple Sandstone and other members of the Jhelum series are all absent from the Kalabagh area. Eight or nine miles up the Lunai, a small stream which enters the Indus a couple of miles to the east of Kalabagh, there is another smaller isolated exposure of salt and red marl surrounded by Upper Tertiary beds.

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[1] Professor W. B. R. King is of opinion that this supposed "*Olenus*" is allied to *Blackwelderia* or some similar Middle Cambrian genus (Private communication).

[2] See C. D. Walcott. Researches in China, III, Cambrian Fauna, 75 (1913).

[3] The identification of an incongruous *Fenestella* was a mistake.

In the southwestern end of the Khasor range, at the base of the Kingriali scarp near Saiduwali, is an isolated but important exposure of the Jhelum series. Here the base of the succession is hidden beneath the alluvium of the adjoining plains. The Purple Sandstone of this locality, of which nearly 270 feet are exposed, is of a slightly deeper purple than usual, but its identity is corroborated by the character of its heavy mineral content. The Neobolus Shales are here more arenaceous and dolomitic, and show a less defined junction with the underlying Purple Sandstone than they do in the Salt Range. They possess the same heavy mineral assemblage as the cis-Indus equivalents, and consist of grey-green sandstones, shaly sandstones and sandy shales, the last with some bands of maroon sandstone ; towards the top occur thin intercalations of gypsum. The white or light grey, brown-weathering dolomites and dolomitic sandstones of the Magnesian Sandstone stage are described by Gee as less massive and as including some thin bands of gypsum. The boundary between the presumed Neobolus Shales and Magnesian Sandstone beds is a purely arbitrary one, and the two stages attain a combined thickness of 250 feet. Succeeding them is a gypsum-dolomite group, some 400 feet thick. It is presumed to be the equivalent of the Salt Pseudomorph stage, though lithologically dissimilar, and consists in the lower part of massive white or light grey, sometimes pink, gypsum with bands of hard, fine-textured, often vesicular, grey dolomite, and black bituminous shales and flaggy dolomite with minor bands of purple and grey-green fragmentary shale ; the upper part of the stage includes a greater proportion of dark grey, flaggy dolomite, often smelling strongly of bitumen, and alternating with white or grey gypsum and some light greenish-grey shales[2]. Some of the thickly-bedded gypsum is black and bituminous ; other layers contain bipyramidal crystals of quartz. As Mr. Gee remarks, the thin bands of gypsum in the Magnesian Sandstone and basal Salt Pseudomorph beds of the Chittidil and Chhidru exposures in the western part of the cis-Indus Salt Range should prepare us for the gypseous nature of the Saiduwali Cambrian beds on the other side of the river.

KANGRA DISTRICT, PUNJAB.

Subdivision—Whatever may be the geological position of the Haimanta formation in Garhwal and Ngari Khorsum, the middle and upper subdivisions of that system, as found in Spiti—the Babeh system of Stoliczka—were included by Hayden as part of the Cambrian. Rocks containing Cambrian fossils were discovered by him in the Spiti valley of the Kangra district of the Punjab, and designated the Parahio series[3]. With the underlying " Upper Haimanta " and " Middle Haimanta " it was grouped to form what was regarded as the local representative of the Cambrian system :

(c) Parahio series . . .	Fossiliferous slates, quartzites and dolomites ; thickness nearly 1,200 feet.

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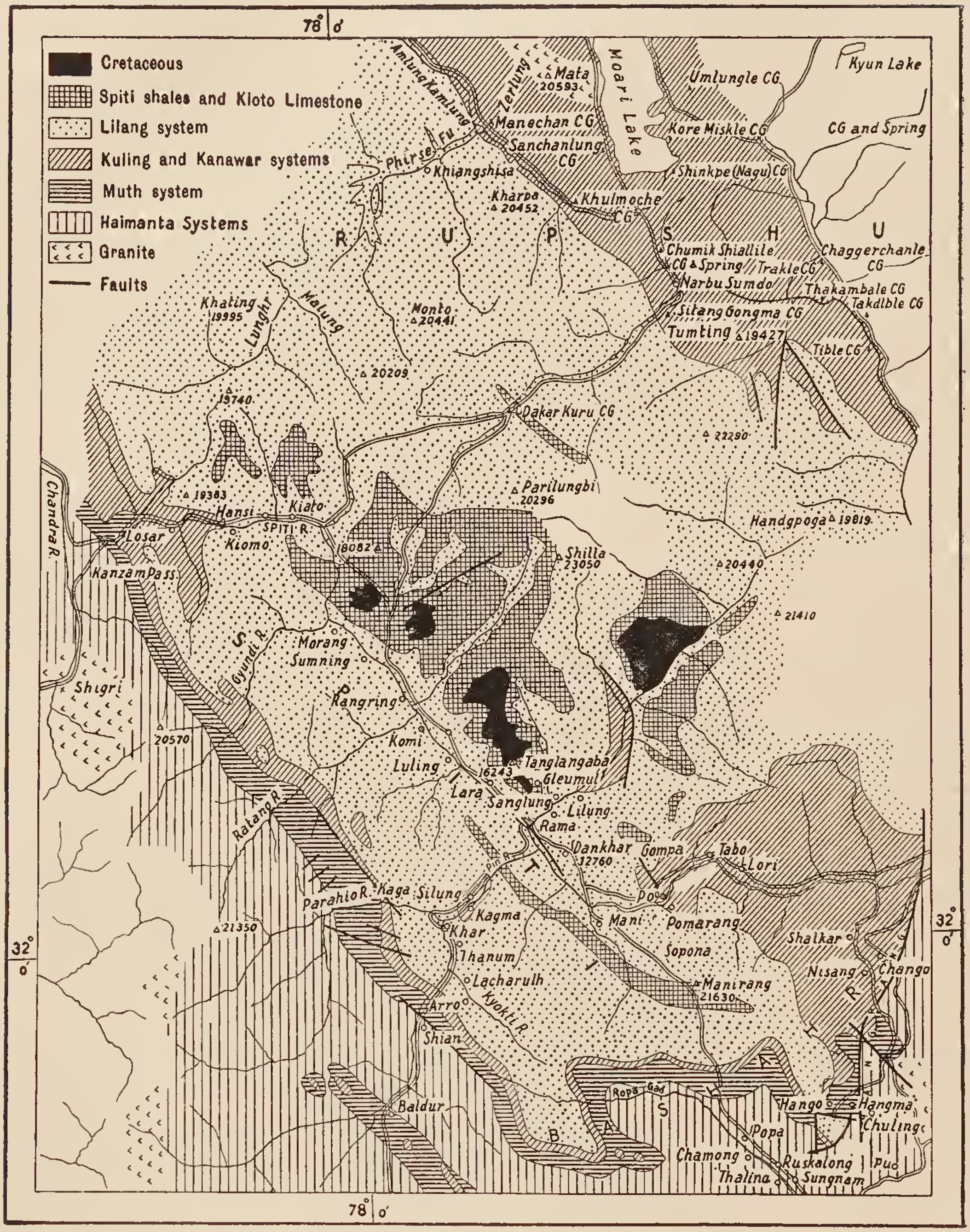
[1] E. R. Gee. *Rec.*, LXIII, 52 (1930).
[2] E. R. Gee. Private communication.
[3] *Mem.*, XXXVI, 13 (1904).

MANUAL OF THE GEOLOGY OF INDIA AND BURMA, 3RD EDITION.


Cretaceous
Spiti shales and Kioto Limestone
Lilang system
Kuling and Kanawar systems
Muth system
Haimanta Systems
Granite
Faults
78° 0'
32° 0'
Moari Lake
Kyun Lake
Umlungle CG
Kore Miskle CG
CG and Spring
Shinkpe (Nagu) CG
Mata 20593
Manechan CG
Sanchanlung CG
Amlung Kamlung
Zerlung
Phirse Fu
Khiangshisa
Kharpa 20452
Khulmoche CG
R U P S H U
Chumik Shiallile CG
Spring
Trakle CG
Chaggerchanle CG
Narbu Sumdo
Thakambale CG
Takdible CG
Sitang Gongma CG
Tumting 19427
Tible CG
Khaling 19995
Lunghr
Malung
Monto 20441
20209
19740
Dakar Kuru CG
22290
19383
Hansi
Kiato
Spiti R.
Parilungbi 20296
Handgpoga 19819
Chandra R.
Losar
Kiomo
18082
Shilla 23050
20440
Kanzam Pass
21410
S P I T I
Gyundi R.
Morang
Sumning
Shigri
Rangring
20570
Komi
Luling
16243
Tanglangaba
Gleumul
Lara
Sanglung
Lilung
Rama
Ratang R.
Dankhar 12760
Gompa
Tabo
Lori
Parahio R.
Kaga
Silung
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Kagma
Khar
Mani
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21350
Thanum
Sopona
Shalkar
Lacharulh
Manirang 21630
Nisang
Chango
Kyokti R.
Arro
Shian
Ropa Gad
B A S H A H R
Baldur
Hango
Hangma
Chuling
Popa
Chamong
Ruskalong
Pu
Thalina
Sungnam

GEOLOGICAL MAP OF SPITI AND RUPSHU

After H. H. Hayden and A. von. Krafft: Mem., Geological Survey of India, XXXVI, pt. I

SCALE, 0 8 16 24 MILES

G. S. I., Calcutta.

(*b*) Upper Haimanta series .	Bright red and black (ferruginous and carbonaceous) slates with some quartzites: thickness about 1,000 feet.
(*c*) Middle Haimanta series .	Dark slates and quartzites: thickness probably between 2,000 and 3,000 feet.

No fossils have been found in the two lower subdivisions, but the beds were thought to form a perfectly continuous sequence and were in consequence grouped under one system. The rocks occupy a broad irregular belt curving from the Chandra river S.S.E.' wards and eastwards across the Sutlej river concentric with the Spiti valley, and constituting to a large extent the great snowy range separating Spiti from Kulu and Bashahr. It is bounded on the southwest by the so-called "Central Gneiss"—a metamorphosed granite intrusive into the Cambrian and later rocks—and by crystalline schists. The Middle and Upper Haimantas of Garhwal have been shown by Auden to be the equivalents of the Simla Slates, and have already been described. It has been assumed that the Haimantas of Spiti were correctly identified as such by Hayden, and these rocks have also been described under the general heading. The only point of interest to be raised here is the claim that the Upper Haimantas pass up conformably into the fossiliferous Parahio series; the confirmation of such a passage would make it necessary to regard part at least of the Haimanta succession—and, consequently, part at least of the Simla Slates and equivalent Himalayan formations—as belonging to the Cambrian rather than to the Purana.

Parahio series.—The upper or siliceous beds of the Upper Haimanta series in the Parahio valley are said to pass up gradually into a series of grey and green micaceous quartzites and thinly-foliated slates and shales, with narrow bands of light grey dolomite. The slates, usually dark blue or black in colour, and varying from a soft argillaceous rock to a hard, siliceous, highly micaceous variety, are very finely laminated and much crushed; the direction of foliation is usually oblique to the bedding, the rock frequently resembling a needle shale. For many hundred feet the following alternation is repeated with great regularity: argillaceous slates passing up into more siliceous varieties and into quartzite which is almost invariably capped by a few inches of calcareous quartzite or dolomitic limestone; this limestone is succeeded by more argillaceous slates, and so on. Towards the top of this succession were found the fossils, mostly in the argillaceous beds but also in the narrow limestone bands and sometimes in the flaggy quartzites. The lowest fossil-bearing horizon is the top of the reddish quartzites overlying the bright red slate series. The Parahio beds of Spiti have not so far been recognised in the Kumaon section of the Himalaya.

Subdivision and fauna of the Parahio series.—The Parahio series has been divided by Hayden into six zones and by Cowper Reed into three stages,[1] according to the fauna :—

Upper stage. Zone 6.
  Trilobita.
    Bathyuriscus (?) *stoliczkai* Reed,
    Dicellocephalus (?) *interpres* Reed
    Olenus (?) *haimantensis* Reed,
Middle stage. Zone 5.
  Trilobita.
    * *Microdiscus haimantensis* Reed,
    Oryctocephalus salteri Reed (abundant),

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[1] *Pal. Ind.*, Ser., XV, Vol. VII, Mem. 1, 62 (1910).
*With American affinities.

* *Ptychoparia consocialis* Reed,
,, *admissa* Reed,
,, *maopoensis* Reed (abundant),
,, (*?*) *hostilis* Reed,
,, (*?*) *prœterita* Reed,[1]
,, (*Conocephalites*) *memor* Reed,[2]
* *Schangtungia* cf. *frequens* Dames.
Pteropoda.
* *Hyolithes* (*Orthotheca*) aff. *plicatus* Brögger.
* *Hyolithes* aff. *danianus* Walcott (two specimens).
Brachiopoda.
Obolus (*Westonia*) *?* sp.,
* *Obolella* cf. *crassa* (Hall) ? (species found in the Lower Cambrian of America),
Acrothele vertex Reed,
* ,, cf. *spurri* Walcott (species found in the Lower Cambrian of America).

Middle stage. Zone 4.

Trilobita.
Ptychoparia spitiensis Reed,
,, *stracheyi* Reed,
,, *urceolata* Reed,
* ,, *defossa* Reed,
* ,, (*?*) *himalaica* Reed,
,, (*Conocephalites*) *hesterna* Reed,
Agraulos (*?*) *simulans* Reed,
Brachiopoda.
Lingulella haimantensis Reed,
,, *spitiensis* Reed (plentiful).
* *Obolella* cf. *atlantica* Walcott,
Acrothele prœstans Reed (two specimens),
,, sp.
Echinodermata.
* *Eocystites* sp. (two plates only).

Middle stage. Zone 3.
Trilobita.
Ptychoparia (*Liostracus*) *civica* Reed.
Brachiopoda.
? Lingulella haimantensis Reed.
* *Acrotreta parahioensis* Reed (plentiful).

Middle stage. Zone 2.

Trilobita.
Microdiscus griesbachi Reed,
**Zacanthoides indicus* Reed,
Oryctocephalus cf. *reynoldsi* Reed,
Ptychoparia pervulgata Reed,
**Agraulos* aff. *roberti* Matthew,
,, (*?*) *fervidus* Reed.
Brachiopoda.
**Botsfordia* (formerly *Lingulella*) cf. *cœlata* (Hall *?*)
Cœlenterata.
Cosinocyathus cf. *corbicula* Bornemann.

Lower stage. Zone 1.
Brachiopoda.
**Nisusia depsaensis* Reed.
Lingulella ? sp.

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*With American affinities.

[1] Almost inseparable from *Pt. hostilis.*

[2] F. R. Cowper Reed's "*Ptychoparia* (*Conocephalites*) *memor*". See J. Kobayashi, *Amer. Journ. Sci.*, XXVII, 301 (1934).

In the Pin ravine, W.S.W. of Muth, a head-shield of *Redlichia noetlingi* has been found. Besides this Muth locality, a third was discovered near Changnu in the Parahio river, where a boulder of limestone was found to contain the trilobites *Anomocare conjunctiva* Reed, *A.* sp., *Agnostus spitiensis* Reed (closely allied to three American forms) and an indeterminable species of the brachiopod *Lingulepis.*

Character of the fauna and its relationships.—One of the most striking facts regarding these fossils, which are mostly crushed and fragmentary, is that each zone comprises a distinct fauna peculiar to itself. No species has been observed outside its own special zone ; certainly none ranges through the whole series. The lowest horizons, like those of the European Cambrian, frequently show the so-called "fucoid" markings. Trilobites are overwhelmingly predominant, brachiopods are poorly represented, while of other classes there are only two or three specimens. The Parahio fauna, like that of the Salt Range, contains no species which has been definitely recognised in any other part of the world but, as a whole, shows a distinct resemblance to the Cambrian fauna of the Rocky Mountain province of North America. This is more especially seen in the trilobites. The genus *Oryctocephalus* had previously been recognised only in British Columbia and Nevada, and the two species from Spiti are closely allied to the two or three American species ; the genus *Ptychoparia* is abundant and predominates both in species and individuals on every horizon except the lowest and highest, many of the species being closely related to forms from the western part of North America ; other genera are scarce and *Paradoxides* is absent ; *Zacanthoides* was previously unknown outside the Rocky Mountain province. *Eocystites* is an American genus of cystideans. The *Obolella* of Zone 4 is comparable to *O. atlantica,* a species found in the Lower Cambrian of America, and many of the other brachiopods show close American affinities.

The Parahio fauna has nothing in common with that of the Salt Range and the succession is quite distinct but for a very interesting link which was established by the discovery of the head-shield of *Redlichia noetlingi* in the Pin ravine. As Dr. Cowper Reed remarks, "with the exception of *Redlichia,* which is not found associated with any of the other trilobites and occurs in a different locality and probably on a lower stratigraphical horizon, all the above trilobites are found in one section in the Parahio valley, exposing a conformable series of beds".[1] The *Obolus* (*Westonia*) ? sp. from Zone 5 has much the same outline as *Lingulella fuchsi* from the Salt Range.

The possible occurrence of *Schantungia frequens* and the presence of the two forms *Agnostus spitiensis* and *Redlichia noetlingi,* both of which are closely paralleled in northern China, are scanty links with the Cambrian of that region, but one of the most remarkable features of the Spiti fauna is its much closer affinities with that of the Middle Cambrian of the Pacific slope of western America than with that of China.[2] The relationship of the Spiti beds with either northern or southern Europe is of the slightest and, disregarding the questionable occurrence of *Olenus* in plentiful numbers, is restricted to the presence of a pteropod very close to *Hyolithes* (*Orthotheca*) *plicatus* from the Paradoxides Beds of Sweden, the occurrence of *Ptychoparia* (*Liostracus*) *civica*, which is undoubtedly allied to two Scandinavian species, and the occurrence of a coral close to *Coscinocyathus corbicula* from Sardinia. The genus *Coscinocyathus* is found in north China (Middle Cambrian) and probably also in the Cambrian of Australia; the Spiti species appears to be identical with one from the Cambrian of Siberia. The *Anomocare* and *Chuangia* Middle Cambrian fauna of Persia, which is related to the corresponding fauna in China and still more strikingly to that in Indo-China, has nothing in common with any of the European faunas and very little in common with either the Salt Range or the Spiti fauna; the want of resemblance to the Indian faunas, however, is due probably to small differences in age rather than to a difference of Zoological province.

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[1] *Rec.,* XL, 11 (1910).

[2] F. B. Cowper Reed. *Rec.,* XL, 10, 15 (1910).

Age of the Spiti beds.—With regard to the age of the Spiti beds, the horizon near Muth is probably equivalent to that of the topmost zone of the Kussak stage of the Salt Range, *i.e.*, highest Lower or lowest Middle Cambrian. Of the Parahio beds the bulk belongs to the Middle Cambrian,[1] the fauna of the lower stage is too scanty to determine its precise age, but it is evidently either Lower or Middle Cambrian. The middle stage undoubtedly belongs to the Middle Cambrian and probably reaches low down in that subdivision. The upper stage, in which the most plentiful fossil is the *Blackwelderia*-like trilobite—the very doubtful *Olenus*—is probably Upper Cambrian. The Changnu boulder belongs probably to the Middle Cambrian (Middle or Upper stage of the Parahio series).

Upper boundary.—The Cambrian of Spiti is overlain unconformably by a conglomerate which has been taken as the base of the Ordovician. At this horizon there is a constant lithological break and unconformity throughout Spiti and Bashahr. The highest beds of the Parahio section are found only in that valley; elsewhere the Ordovician conglomerate rests upon lower horizons. Eastwards, in the Thanam valley, for instance, the greater part of the Parahio series has been removed; further east, the trilobite-bearing beds appear to be entirely absent, and on the south side of the Hangrang Pass Ordovician rocks lie upon the red and carbonaceous slates of the so-called Haimanta group. In the latter locality, however, and throughout Bashahr, the rocks are much disturbed and faulted. As already remarked, only the Middle and Upper series of the "Haimanta" have been recognised in Spiti.

KASHMIR.

Lie of the ancient sedimentaries.—The broad outcrop of gneissic and crystalline rocks east of Simla, when traced northwestwards across the Sutlej, splits up in the Kangra district into two branches, the more northern and broader of which follows the range between the Kulu and Spiti valleys into Lahaul and Zanskar, while the more southern extends with a parallel trend through the Dauladhar range into the Pir Panjal, where it thins out to a narrow strip separated only by a band of insignificant width of pre-Tertiary rocks from the sub-Himalayan or Tertiary zone of Jammu. Between these two branches lies a broad area of sedimentaries, while another area of similar rocks runs as a direct continuation of the Spiti succession along the northeast side of the Zanskar branch; these two areas meet each other around the Kashmir valley. Excluding the Tertiary basin of the Indus valley, these sedimentary rocks were included by Lydekker in his "Panjal" and "Zanskar" systems, the former comprising his "Lower Palæozoic" and the latter his "Upper Palæozoic and Mesozoic" rocks. Detailed work on more adequate maps has necessitated extensive modification of Lydekker's rapid reconnaissances, and his "Panjal system" is now known to include in western Kashmir and Chamba, slates and associated beds of Archæan or Purana age or both, as well as early Palæozoic strata and a great succession of Carboniferous and Permian beds; the last-mentioned succession, in fact, forms the principal portion of the system. In eastern Kashmir, where the sequence is a continuation of that found in Spiti, Lydekker's original correlation may be approximately correct, the "Panjal system" being here restricted to the rock series extending from the base of the "Haimanta" to the base of the Kuling system, whose lower limit may be the lower limit of the Upper Carboniferous. The "Panjals" here consist typically of dark-coloured slates and sandstones, but in what proportion the "Haimanta" and Muth systems are represented is not known.

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[1] *Gen. Rep., Rec.*, XXXVII, 27 (1908).

Graywacke group.—Amongst the beds originally grouped in western Kashmir as "Panjals" Middlemiss has identified in the region to the east of Islamabad a thin band containing Silurian fossils and overlying "many hundreds of feet" of a graywacke group composed of pale, drab-coloured, thin-bedded slaty shales and fine, compacted, earthy sandstones, which must be looked upon as either Ordovician or Cambrian or both. The beds are frequently sandy or micaceous but never massive or quartzitic. In the upper parts are calcareous layers which locally attain some thickness but in which no trace of fossils has been found; these limestones, which are much altered, possibly represent the Ordovician limestones of Spiti. In the other components of the formation, fossils are not wanting but have so far proved quite indeterminable; they are more numerous and less ill-preserved in the highest beds but become more and more effaced the deeper their horizon, until they are reduced to mere rusty spots and blotches.

The above graywacke beds form a great steep anticlinal fold about a N.W.—S.E. axis a few miles east of Islamabad, pitching towards the northwest. This anticline is succeeded on the northeast by a steep syncline involving younger beds, and this syncline in turn by another outcrop of the graywackes along the Wardwan valley, the two outcrops of graywacke meeting each other southeastwards where the syncline rises (see map, facing p. 638). There can be little doubt that further southeast, still larger areas are composed of these ancient Palæozoic rocks.[1] Underlying the Panjal volcanic rocks, which are so extensively developed along the summit of the Pir Panjal, Wadia found a considerable thickness of Lower Cambrian, as well as of Lower and Middle Carboniferous strata, exposed in a series of open, northwesterly-pitching anticlines and synclines, between Budil and Banihal. These Cambrian beds, consisting of clays and slates with quartzite partings, contain copious annelid markings and a few indistinct pteropod shells, and are unconformably overlain by 3,000 feet of Lower Carboniferous limestone (Syringothyris Limestone).[2]

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[1] C. S. Middlemiss. *Rec.*, XL, 211-213 (1910).

[2] *Gen. Rep.*, *Rec.*, LXXII, 75 (1937).

According to Middlemiss, the lower reaches of the Sind valley, northeast of Srinagar, mapped by Lydekker as belonging to his "Panjal system," consist of the same drab-coloured slates, phyllites and graywackes, with rare calcareous layers, already described as occurring further south. These Sind valley beds are in all probability a continuation of the Wardwan valley exposure. The slates are frequently micaceous and contain relics of fossils in the form of ferruginous patches similar to those described above. The fossiliferous Silurian band could not be found in the Sind valley, but Middlemiss speaks of thin-bedded Silurian slates, succeeded in the characteristic way by a rather thin but very typical outcrop of the Muth Quartzite. Near Margund these old graywackes and slates have suffered intrusion by biotite granite.

The age of at least part of this graywacke formation, which Middlemiss with so much foresight assigned tentatively to the Cambrian, has fortunately been definitely confirmed by the recent discovery by D. N. Wadia of Cambrian fossils in beds of the same description further west, *i.e.*, in the mountainous country which forms a semi-circle enclosing the western extremity of the Kashmir valley, between the Pir Panjal and that off-shoot of the Great Himalaya known as the North Kashmir range.[1] As already noticed, the occurrence of fossiliferous Palæozoic sediments on the south side of the main Himalayan axis is a feature almost unique to the Kashmir end of the chain; further east Palæozoic and Mesozoic Himalayan faunas are, with one or two rare exceptions, confined to the Tibetan zone.

Relationship to the Dogra Slates.—Towards the centre of the Palæozoic synclinal basin under consideration, which is exposed in an elliptical outcrop distorted by minor folding, the Dogra Slates—already described under the heading of Purana—are said to pass up through passage beds into strata bearing many indeterminable but undoubted organic remains, and these in turn with no hiatus into beds containing recognisable trilobites and brachiopods of Middle or Upper Cambrian affinities. The lower portion of this great system of partly fossiliferous clays, slates, limestones and arenaceous beds, therefore, probably includes Lower Cambrian strata and perhaps also pre-Cambrian deposits, for the lowest horizons have been found by Wadia to pass, not only vertically, but also laterally into slates of the Dogra type. In the outlying parts of the basin, in fact, some of the Dogra Slates have the appearance of being but a variant facies of the obscurely fossiliferous slates, quartzites and shales of presumably Lower Cambrian age. The vertical passage of the Dogra Slates into Cambrian—and incidentally of the latter into the Ordovician—is said to be well seen in a traverse across the Jhelum-Kishanganga dividing range from Jumegand to Marhaum. In some places, the relationship of the Dogra Slates to the lower horizons of the Cambrian sequence is obscure, and to what extent the two formations are separable and distinct is not yet clear.

Lower Cambrian.—In what we may tentatively call the Lower Cambrian of this area, there are no limestones, the predominant rock being a dark laminated slate with quartzose partings; the slate shows an imperfect cleavage oblique to the lamination and more apparent than the latter. The ripple-marked surfaces of many of the sandy beds are crowded with annelid markings in the form of convoluted or straight casts, tubes, tracks and burrows, varying from thin threads to tapering or conical pipes sometimes two inches in diameter; these beds have characters in common with the annelid sandstones of the Kussak stage in the Salt Range.

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[1] *Rec.*, LXVIII, 122-123, 134 (1934).

In some places the Lower beds are missing and the Salkhala series is overlain by the younger portion of the Cambrian sequence. In the north, the older Cambrian has been invaded by a granite called by Wadia the Hant Granite and also by long narrow veins and sills of the "Central Gneiss". Elsewhere, the beds are unaffected by granite intrusions but are traversed by a series of quartz veins, some of which contain disseminations of chalcopyrite. The older Cambrian is copiously seamed by dykes of black, fine-grained dolerite, 20 to 100 feet thick, and belonging presumably to the Panjal Trap.

Middle and Upper Cambrian.—The Lower Cambrian—if so correctly designated—passes with perfect conformity up into higher beds referable to the Middle Cambrian and perhaps including some at least of the Upper Cambrian. These beds are exposed along the foot of the mountain of Shamsh Abari, west of Handwara (Hundawor), in a pitching syncline, on the northern flank of which they cover a comparatively wide tract. Further east, they are seen in more or less isolated patches but are here largely concealed under the alluvium of the Lolab and Pohru rivers and their tributaries or under the Karewah deposits of Pleistocene age.

This younger sequence consists of thick-bedded, unlaminated but imperfectly cleaved clays of bright blue colour, grey and green sandy slates which are at times micaceous, and brown ferruginous sandstones. The argillaceous beds are copiously intercalated with limestones carrying many oolitic and a few pisolitic layers. These calcareous interoalations increase in importance towards the top of the series but are as a rule devoid of determinable fossils. Some of the calcareous beds, especially those in the Bijildhar valley, have the appearance of being algar limestones.[1]

Like the older series, the younger Cambrian is traversed in all parts by feeders of the Panjal Trap in the form of basic dykes. At one locality, in the centre of the Marhaum syncline, the beds are overlain by strata with Ordovician forms of *Orthis* and other brachiopods.

Fauna.—Organic remains, which are restricted to the argillaceous and sand-beds, have been mostly reduced to mere rusty blotches and discolorations. Determinable specimens have, however, been obtained by Wadia from several localities but are extremely sporadic. The specimens consist principally of small trilobites, represented by isolated cranidia, usually in a crushed or fragmentary condition, of small horny brachiopods mostly in a poor state of preservation, and of a few pteropods.[2] In spite of local differences in faunal composition and of certain lithological differences in the rocks, all the fossils are referred by Dr. Cowper Reed to the Middle or Upper Cambrian, on the strength of the affinities of the species, which are mostly new. The most striking feature of the fauna is the occurrence of the peculiar genus *Tonkinella*, previously found only in Tonkin and of species of *Conocoryphe*, *Anomocare* and other genera allied to those in the Cambrian of French Indo-China.[1] The two genera *Anomocare* and *Chuangia* also link these beds with the Persian fauna at or just below the base of the Upper Cambrian. The following is a list of species obtained from horizons which probably vary somewhat in level but which have so far not been differentiated :—

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[1] C. S. Middlemiss. *Rec.*, XL, 211-213 (1910).

[2] *Gen. Rep.*, *Rec.*, LXXII, 75 (1937), D. N. Wadia., *Rec.*, LXVIII, 123, 134 (1934). D. N. Wadia. *Rec.*, LXVIII, 138 (1934). F. R. Cowper Reed. *Pal. Ind.*, New Ser., Vol. XXI, Mem. 2, p. 1 (1934).

- Cystidea.
  - *Eocystites* (?) sp.,
  - *Hazelia* (?) sp.,
- Brachiopoda.
  - *Obolus kushmiricus* Reed,
  - *Lingulella* sp.,
  - *Lingulepis* (?) sp.,
  - *Botsfordia* cf. *cœlata* (Hall)
  - *Acrothele* aff. *subsidua* White
  - *Dicellomus* cf. *politus* (Hall)
- Gastropoda.
  - *Lapworthella* (?) sp.,
  - *Hyolithes* cf. *cybele* Walc. ?
  - ,, (*Orthotheca*) cf. *daulis* Walc. ?
  - ,, ,, cf. *lineatulus* Holm. ?
- Trilobita.
  - *Agnostus* cf. *rakurœnsis* Kobayashi,
  - *Microdiscus* sp.,
  - *Conocoryphe frangtengensis* Reed,
  - ,, *sejuncta* Reed,
  - ,, (*Ctenocephalus* ?) sp.,
  - *Tonkinella breviceps* Kob. (equivalent probably) *T. Kashmirica* Reed,
  - ,, *quadrifida* Reed,
  - *Dolichometopus subtuberculatus* Reed,
  - *Corynexochus* sp.,
  - *Anomocare hundwarense* Reed,
  - ,, *novatum* Reed,
  - ,, *suspectum* Reed,
  - ,, *dimotum* Reed,
  - ,, (?) *perfunctum* Reed,
  - *Chuangia wadapurensis* Reed,
  - ,, *subangulata* Reed,
  - *Solenopleura lydekkeri* Reed,
  - *Blountia* (?) sp.,
  - *Ptychoparia dardapurensis* Reed,
  - ,, *memor* Reed,
  - *Changshania* (?) *nupera* Reed,
  - *Saukia* (*Briscoia* ?) *vagans* Reed,
  - *Prosaukia middlemissi* Reed,
  - *Hundwarella personata* Reed,
  - ,, (?) *remota* Reed,

Agnostus rakuroensis and *Tonkinella breviceps* are both found in the Cambrian of Cho-sen. *Hundwarella* is an entirely new genus. *Anomocarella memor* is a Spiti form ; the doubtful Kashmir specimen is much like Mansuy's *Anomocare* cf. *megalurus* (Dames), and to a similarly compared species occurring in the Cambrian of Persia.[2]

Age and correlation of the beds.—With regard to the age of the Kashmir beds, Cowper Reed concludes that the greater part belongs to the Middle Cambrian, " though the affinities of several of the trilobites and brachiopods, being with those of Upper Cambrian age in America and elsewhere, suggest that some higher Cambrian beds may also be represented in the collection." The scanty

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[1] See A. Mansuy. *Mem. Serv. géol. Indo-Chine*, IV, Fasc. 2 (1915) ; *Ibid.* V, Fasc. 1 (1916).

[2] T. Kobayashi. *Amer. Journ. Sci., Ser.* 5, Vol. XXVII, 295-302 (1934) ; See also W. B. R. King. *Geol. Mag.*, LXVII, 318(1930).

Cambrian faunas from eastern Yunnan appear to belong to a lower horizon than any represented in the Kashmir assemblage and are therefore not comparable. The very limited Dead Sea fauna is a specialised one and is also, for that reason invalid for comparison. The nearest Cambrian fauna in India, that of the Salt Range, is completely distinct, but this may be partly due to the fact that in this assemblage brachiopods predominate and trilobites are very scarce, while in Kashmir on the other hand trilobites outnumber the brachiopods. The rich Cambrian faunas of the Spiti area also contain an entirely different assemblage, and not a single species thereof, with the exception of the doubtful *Anomocarella memor*,[1] as found in the Kashmir beds. Of the rich and varied faunas of Lower, middle and Upper Cambrian age in northern China, none bears any great similarity to that of Kashmir, though some species are noticeably allied and the genus *Chuangia* is apparently present in both areas as well as in Tonkin.[2] The relationship of the Kashmir fauna is closest with the faunas of Indo-China and Persia, though the trilobite *Redlichia*, so typical of the two latter countries, is absent. In spite of the specific differences, Mr. Kobayashi is of the opinion that, the Handwara zone of Kashmir—as he calls it—is the equivalent of the top horizon of the Middle stage of the Parahio series, and correlates it with the *Tonkinella flabelliformis* zone of Indo-China and Yunnan, the *Olenoides* zone of Cho-sen, the Stephen formation of western North America, and probably the Templeton formation of Mount Isa, Queensland.[3]

BURMA.

No Cambrian fossils have so far been discovered within the confines of Burma and the oldest fossiliferous strata in that country are of Lower or early Middle Ordovician age, and are known as the Lower Naungkangyi beds. In the Northern Shan States, these beds pass down through an unfossiliferous series known as the Pangyun into the Bawdwin Volcanic series. The whole succession appears to be a conformable one, although the volcanic disturbance seems to have lasted longer in the Southern Shan States than it did further north. This conformity does not preclude the possibility of part at least of the Bawdwin Volcanics and part of the Pangyun series representing the younger portion of the Cambrian. If the rhyolites found in what is known as the Pindaya series in the Southern Shan States are correctly regarded as belonging to the Bawdwin suite, as they almost certainly are, this acid phase of vulcanicity must have persisted, locally at any rate, into the Ordovician.

BAWDWIN VOLCANIC SERIES.

Position and relationships.—At certain localities along the boundary between the Chaung Magyi beds and the overlying fossil-bearing Palæozoic formations in the Northern Shan States of Burma, there is exposed a series of tuffs or ash beds interstratified with layers of rhyolite. The most important development of these beds so far met with occurs at Bawdwin (Bawdwin-gyi) in the Tawng-peng State, a few miles west of the village of Nam-tu. This place was, for many hundreds of years, the site of extensive mining operations on the part of the Chinese who extracted large quantities of silver from the silver-lead ores found among the tuffs and rhyolites. The early history of the mines dates back to the 14th century and the Chinese did not abandon operations till the Mahomedan rebellion in 1868. The mineral deposits are now being exploited by a British company and shafts have been sunk into the intensely shattered mineralised zone which occurs along a great overthrust traceable for many miles to the south of Bawdwin. The date of the dislocation and the mineralisation which followed is not definitely known, but there are grounds for regarding both as connected with the intrusion of a granite which in the Northern Shan States has been designated the Tawng-peng Granite. This intrusion was at first thought to be the plutonic phase of the Bawdwin rhyolites but the evidence, scanty as it is, seems more in favour of the view that the Tawng-peng Granite, with the mineral veins and lodes connected therewith, is considerably younger than the rhyolites, and may perhaps date from some period between the earliest phase of the Plateau Limestone (Devonian) and the Rhætic. This granite and its supposed mineralising accompaniments will be described in a later chapter.

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[1] And a doubtful hyolithoid which may be close to Reed's *Hyolithes* aff. *danianus* Walc.

[2] F. R. Cowper Reed. *Pal. Ind.*, New Ser., Vol. XXI, Mem. 2, p. 2 (1934).

[3] *Amer. Journ. Sci.*, XXVII, 296 (1934).

Age.—South of the Bawdwin area, the volcanic beds are almost everywhere overlapped by Silurian sandstones. Among the few places in the Northern Shan States where they reappear are: (i) Lawngtawktao; (ii) Kunhawt, further south, where there is a small exposure of spherulitic rhyolite; and (iii) between Kunhawt and Hunang. In the ranges east of the Shan plateau, they are found along the crest of the Loi-len range, east of Lashio; among the hills between Mong Yai and the Nam Ha valley; and on the western side of Loi Twang, south of Mong Tung. In the Bawdwin region itself, their lower horizons are cut out by overthrusting, but at every other locality where they are present, they invariably occur between the Chaung Magyi rocks and the lowest member present of the Palæozoic fossiliferous succession; they do not, however, form a continuous band.

It was at first thought that, as the deposition of the overlapping younger beds had in places been preceded by sub-aerial denudation, it was permissible to group the Bawdwin Volcanics with the Chaung Magyi series under the same system instead of with the lowest subdivision of the fossiliferous rocks. Recently discovered facts, however, make it preferable to regard the volcanic beds as part of the oldest Palæozoic sequence of Burma. In the first place, there is, apparently, a gradual and conformable passage down from the lowest Naungkangyi beds (Ordovician), through the unfossiliferous Pangyuns—when the latter are present—into the Bawdwin tuffs and rhyolites.[1] Secondly, in the Southern Shan States, rhyolites believed to belong to the Bawdwin suite are actually interbedded with sediments containing Ordovician fossils.

The Bawdwin exposure as a whole is regarded by Coggin Brown as forming a kind of low dome, lying N.W.—S.E., and rising from beneath the Pangyun beds, the lowest horizons of which are composed of thin felspathic grits full of tuffaceous matter and partake of the nature of passage beds.[2] Other patches of rhyolite occur both to the north and east of Bawdwin. The base of the rhyolitic series is not visible at Bawdwin but in other parts of the Northern Shan States overlies the Chaung Magyi beds unconformably. In the Bawdwin Mine, however, lying below the rhyolite suite, sedimentary rocks of Chaung Magyi character have been encountered, showing an unconformable relationship with the Pangyun beds. These Chaung Magyi sediments occupy the whole of the known bottom of the Bawdwin Mine and have been penetrated by the drill to a depth of several hundred feet. The rhyolitic suite does not appear to be continuous over great distances but seems to have been formed at isolated centres. In most cases, it is more or less completely overlapped by higher beds.

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[1] E. L. G. Clegg. *Rec.*, LXXV, Prof. Paper 13, p. 4 (1941).
[2] *Rec.*, XLVIII, 140 (1917).

Composition.—The beds consist of rhyolitic and other tuffs, rhyolites, occasional bands of volcanic breccia, subordinate layers of sandstone and felspathic grit and, according to Leicester, intrusive quartz porphyries.

The Lavas.—The rhyolites, subordinate in quantity to the tuffs, exhibit the usual phenomena observable in acid glassy lavas, such as flow, spherulitic and perlitic structures, corrosion of the quartz phenocrysts, and other features. They are pink, brown or chocolate in colour, and often full of grains of clear secondary quartz. The groundmass is always cryptocrystalline—having probably undergone some devitrification—and sometimes exhibits under crossed nicols the peculiar breaking-up into irregular, alternately light and dark areas, known as a "quartz mosaic." The felspars of the rhyolites, both phenocrysts and those of the groundmass, are usually quite decomposed; when sufficiently fresh for identification, they are seen to consist invariably of orthoclase in which traces of simple twinning can sometimes be made out. Iron ores, exhibiting the white mesh-work characteristic of leucoxene, are usually present, but no trace of any ferromagnesian mineral or of mica has been observed. Phenocrysts of quartz preponderate over those of felspar. In the mine, typical rhyolites are much smashed and broken by fault-planes; in rare instances lumps of graphitic slate have been found included in them.[1]

The "quartz mosaic" structure in the Bawdwin rhyolites, as noted by La Touche, is exactly the same as that which occurs in some of the Malani rhyolites of western Rajputana; in the rocks from both localities, wherever this structure occurs, the quartz phenocrysts are surrounded by a "court" or closed area, the quartz of which is in optical continuity with that of the phenocryst. An exactly similar structure has been noted in rhyolites interbedded with the Deccan traps and therefore of late Cretaceous or early Tertiary age. The Bawdwin and Malani rhyolites further resemble each other and differ from the Deccan lavas in the preponderance of quartz phenocrysts over those of felspar, and in the absence of plagioclase felspar and augite.

The Tuffs.—The tuffs, which form by far the greater part of the series, resemble the flows in composition and consist of fragments of quartz and felspar, and occasionally of rhyolite, embedded in a fine-grained matrix of volcanic dust. They have undergone such extensive metamorphism that it is not always easy to say where the rhyolite ends and the tuff begins. The typical tuffs differ from the rhyolites in having no flow-structure, in showing evidence of clastic origin, and in being more altered. The distinction between the silicified tuffs and the grits of the Pangyun series is said to be still more difficult. The felspar of the tuffs is generally in as decomposed a condition as is that of the lavas. The occurrence in the matrix of occasional fragments of rhyolite showing the mosaic-structured groundmass alluded to above makes it probable that this structure was developed in the lava at the time of its consolidation and is not a result of subsequent devitrification. The tuffs are often chloritised. One has been observed to contain spherulites and small shaly inclusions, and in places thin quartz veins. Underground, the tuffs are honeycombed to such an extent as to resemble pumice. At the surface they are usually soft, as a result of kaolinisation, and of a light grey colour. Felspathic grits, quartzites and thin bands of true rhyolite are all found associated with the tuff beds themselves.

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[1] E. L. G. Clegg. *Rec.*, LXXV, Prof. Paper 13, p. 5 (1941).

Mohochaung.—Some twenty-five miles northeast of Bawdwin are the old Chinese lead mines of Mohochaung. No rhyolite is present, but the ore-bodies occur in sandstones and shales which are thought to be contemporaneous probably with the Bawdwin sediments.[1] A coarse muscovite-biotite granite crops out a little to the west.

Myitkyina.—The Lagwi Pass on the China-Myitkyina frontier is occupied by dark grey, fine-grained, siliceous tuff, composed of sharply angular quartz fragments lying in finer, chloritised material. This tuff, belonging presumably to the Bawdwin suite, is in contact on the west with the granitic gneiss, on the east with crystalline limestones described as similar to those near Kamaing in the Hukawng valley ;[2] at the contact between the limestones and the tuff occurs a band of crystalline zoisite. Along this junction also are the Chinese galena mines of the Shweli-Nmai Kha divide, occurring in a pegmatite together with pyrite and chalcopyrite.

Southern Shan States.—The localities enumerated above, with the exception of Myitkyina, are all situated in the Northern Shan States, but in the neighbourhood of Ngot-to-ya-gyi and of Mene-taung, in the Southern Shan States of Pindaya, rhyolites, which no doubt belong to the Bawdwin suite, are actually interbedded with limestones and shales of Ordovician age (Pindaya beds). In Pindaya, the volcanic rocks are described as light-coloured with reddish brown spots due to the decomposition of pyrite ; being always in a very decomposed condition, they rarely exhibit flow structures. It is significant that sulphides of copper, lead and antimony occur in the vicinity of these rhyolite exposures.[3]

PANGYUN SERIES.

Forming an irregular belt with a local N.—S. strike, the Pangyun beds[4] enclose the main outcrop and a few small inliers of the Bawdwin Volcanic series. Along their regular eastern boundary, they dip under the Naungkangyi series (Ordovician) ; along the irregular western border, they are, in the south thrust over the Namhsim Sandstones (Silurian), and in the north in unconformable or faulted contact with the Chaung Magyi series.[5] Northwards the beds veer towards the northeast, thin out rapidly through faulting, and disappear completely in the neighbourhood of Namhogyi ; here the series, consisting of purple sandstones and hard felspathic grits, rests unconformably upon the Chaung Magyis, the unconformity being marked by a basal band of coarse conglomerate.[6] Down the middle of the Pangyun outcrop, across the rhyolites, runs the principal thrust-fault of Bawdwin. Maclaren was of the opinion that the Pangyuns overlie the rhyolites unconformably, but Coggin Brown describes the former as passing down into the lavas and tuffs with no stratigraphical break of any consequence, and this is confirmed by Clegg.[1] Where the rhyolitic series is absent through overlap, the Pangyuns lie unconformably upon the Chaung Magyis. By Coggin Brown the series is spoken of as overlain in absolute conformity by the fossiliferous Lower Naungkangyis (Lower or Middle Ordovician) ; M. R. Sahni also, writing of sections much further north, states that the Pangyun beds pass with apparent conformity up into beds containing typical fossils of Lower Naungkangyi age.

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[1] J. Coggin Brown. *Rec.*, LVI, 89-90 (1924).

[2] Murray Stuart. *Rec.*, LIV, 407 (1922).

[3] J. Coggin Brown and V. P. Sondhi. *Rec.*, LXVII, 214, 215, 241, 242 (1933).

[4] The " Banyan Beds " of Maclaren.

[5] *Gen. Rep. Rec.*, LXIII, 93 (1930).

[6] *Gen. Rep. Rec.*, LXV, 87 (1931).

The series is well exposed in the Nam Pangyun, the narrow gorge up which the Burma Mines railway runs from Nam-tu to Bawdwin. In the neighbourhood of Bawdwin, as a result of the overthrusting, the Pangyun beds are characterised by extreme distortion, but further east there is a regular dip to the east, which varies from 45° to about 30° where the beds pass under the Naungkangyis.

In the western part of the Nam Pangyun section, in the neighbourhood of the rhyolites and presumably constituting the lower portion of the series, the rocks consist predominantly of quartzite, with subordinate bands of greenish micaceous slate or purple slaty shale. Among the quartzites occur felspathic grits, some of them with rhyolitic patches and specks of chalcopyrite, others coarsely conglomeratic with small round pebbles of pink rhyolite in a greenish matrix and grains of transparent secondary quartz. As a result of lateral shearing movement, some of the quartzites are crushed, rolled or contorted ; the unfractured types, alternating with bands of purple shale, are frequently well jointed the joint-planes being often curved and marked with horizontal slickenside. Some of the coarser quartzites and grits contain minute nests of malachite and azurite. In the vicinity of Bawdwin, where the junction with the rhyolites is seen, the lowest Pangyun bed is a grit with pink felspathic patches, secondary quartz blebs and ferruginous spots. Interbedded shales increase towards the top, and the last two types, just below the Naungkangyi boundary comprise dark purple ripple-marked sandstones often interbedded with shaly material, overlain by purple shales and thinly-bedded purple sandstones. The arenaceous beds of the series vary from practically pure quartzite to a fine-grained sandstone.[2]

This formation may form part of an outlier on the Memauk spur, and may occur in other parts of the Northern Shan States. A series of hard, blue and purple sandstones, shales and grits, with occasional intercalations of conglomerate, is to be seen lying upon Chaung Magyi rocks and overlain by fossiliferous Lower Palæozoic sediments in the northern half of Lawksawk, one of the Southern Shan States, and in the adjoining parts of the Kyaukse district, and may be referable to the Pangyun.[3]

YUNNAN AND TONKIN.

A Lower Cambrian fauna of considerable size has been described from southern Yunnan, the commonest and most characteristic trilobite being *Redlichia chinensis*.[4] This fossil has also been found in eastern Yunnan by Coggin Brown.[5]

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[1] *Rec.*, XLVIII, 146 (1917) ; *Ibid.* LXXV, Prof. Paper 13, p. 4 (1941).

[2] E. L. G. Clegg. *Rec.*, LIV, 432 (1922).

[3] *Gen, Rep. Rec.*, LXXI, 66 (1936).

[4] A. Mansuy. *Mem. Serv. géol. Indo-Chine*, Vol. I, Fasc. 2, 19-31 (1912) ; *Bull. Serv. géol, Indo-Chine*, Vol. VI, Fasc. 6, 9-22 (1919).

[5] *Rec.*, XLIV, 99 (1914).

In northern Tonkin and the adjacent parts of southeastern Yunnan, a much richer fauna, indicating the presence of Middle and Upper Cambrian, has been found. In this assemblage were 18 new species—including 2 new genera—but a large number of the trilobites and brachiopods were found to be identical with forms from northern China.

CAMBRIAN GEOGRAPHY.

Of the Indian Cambrian faunas, those of the Salt Range belong to a horizon very close to the boundary between the Lower and Middle Cambrian. The Spiti faunas also include the *Redlichia* zone but, in other respects, are quite different in detail ; a few Lower Cambrian types are present, and there are one or two doubtful representatives of Upper Cambrian horizons but the bulk of the fossils are Middle Cambrian species. In Kashmir the sequence may well include the Lower Cambrian, though there is no palæontological evidence for this ; the great majority of the fossils belong to the Middle division, and there are not wanting indications of the presence of higher horizons. If the Archæocyathine and Protolenoid stages of the Australian Lower Cambrian are represented at all in Kashmir and other parts of the Himalaya, it must be by unfossiliferous beds.

In endeavouring to interpret the marked differences between the various Cambrian faunas of Asia, certain facts have to be borne in mind. In the first place, with the exception of those made in north China, most of the collections of these very ancient fossils are extremely scanty and are evidently but small fractions of a much richer fauna—small fractions which, as a result of " collectors' luck ", may not happen to have much in common one with the other. Secondly, most observers remark on the extreme localisation of species in this Cambrian life province, a restriction attributable probably to several factors which influence the character of a fauna, such as the nature of the sea-floor, character of the food supply, temperature of the water and the nature of its dissolved salts. Thirdly, evolutionary changes seem to have been unusually rapid ; as we have seen, the Parahio fauna itself is split vertically into distinct individualistic faunules, and the evidence of such swift vertical change makes it easier to understand the curious lack of resemblance between the Spiti, Kashmir and Salt Range faunas. Bearing such things in mind, it seems safe to conclude that the Cambrian of the Salt Range, Kashmir and Spiti was all deposited off the same coast of a continent which included the Indian Peninsula.

Following Grabau, with slight changes, the Lower and early Middle Cambrian so far known in the world may be grouped into three major marine provinces :—(i) the Atlantic, (ii) the Pacific, and (iii) the Australo-Asian, all quite distinct from one another and characterised by the respective trilobites, *Holmia*, *Olenellus* and *Redlichia*. The Atlantic with its *Holmia* and many hyolithids had its eastern limit in Europe, and in this region are thought to have thrown out two easterly embayments, one across the Baltic Provinces of Russia and the other covering the western part of the Mediterranean. The Pacific province included all quartes of the Arctic region except that to the north of America and Greenland which formed part of the Atlantic continent. The waters of this province are supposed to have been separated from those of the Atlantic, and especially the Baltic embayment thereof, by a very long and narrow land barrier, known as the " Caledonian Old Land ", zigzagging from Norway to Scotland, thence to Iceland

and thence again southwestwards towards Newfoundland. To this Pacific fauna has been referred that of the Irkutsk basin of Siberia, for, although it has yielded only doubtful fragments of the trilobite, *Olcnellus*, it includes *Kutorgina cingulata* Bill., a brachiopod extremely characteristic of this old Pacific ocean.

The province which concerns us more immediately is the Australo-Asian, and more especially a large northward indentation thereof from the Indian Ocean, which appears to have split into two large arms. One of these extended westwards along the Himalayan geo-syncline, through the northern Punjab, across southwest Persia where *Redlichia* and *Anomocare* have been identified, to Mesopotamia ; the western end of this arm has all the characters of a shallow-water, epi-continental sea. The other arm trended northeastwards across Yunnan, Shan-tung and Shan-si, as far as Manchuria, and perhaps a little further, for an undescribed *Protolenus* (*Palæolenus ?*) fauna is apparently present at Sinskaya in Siberia.[1] The other end of this Australo-Asian ocean reached western and southern Australia, and gave habitat to the peculiar sponge *Archæocyathus*, the ball-like algal *Girvanella*, the so called "*Salterella*,"[2] *Howchinella*, *Redlichia*, and many other trilobites. Besides many species of *Redlichia*, this Asiatic fauna includes another trilobite genus, *Palæolenus*, and many brachiopods and ostracods ; the Indian faunas, as we have seen, show signs of specialisation. Glacial boulder beds near Hankow witness to the debouchment of glaciers into the *Redlichia* sea.

During this early part of the Cambrian period, therefore, the Asiatic region possessed two areas of deposition : a northern sea, part of the " Pacific ", covering what are now the Irkutsk basin, parts of the northern coast of Siberia and the Liakov or New Siberian Islands, with an arm extending up the Lena valley ; and a southern sea described in the previous paragraph. Between the two lay the forerunner of the Angara continent. The northern *Olenellus* sea, by way of the Arctic Ocean and north Europe, stretched westwards as far as the region of North America, spreading down the present Atlantic coast from Labrador to Alabama.

In north China the Cambrian deposits of the southern province, where they rest upon Sinian rocks, are rarely unconformable thereto ; elsewhere there is evidence to show that the southern sea covered an old land surface, as indicated by the important discordance which separates the Precambrian from the Cambrian. Evidence of a similar ancient land surface, in earliest Cambrian times, is seen in southwest Persia, bordering the geo-syncline which ran east and west across the line of the present Himalaya.[3] There are no indications of any connection between the Lower Cambrian sea of the Atlantic province and that of China and northern India.[4]

If any of the Haimanta deposits should eventually prove to include marine representatives of the Lower Cambrian—an inference about which there is some doubt—we should have to visualise the Lower Cambrian sea of northern India stretching possibly from Spiti to Nepal, for the Haimanta outcrop is continuous between those regions. From this it would follow that the Aravalli range, in Lower Cambrian times, did not extend into what is now the Tibetan flank of the Himalaya, though it seems to have transgressed for a time into it during the later part of the period, judging from the way the fossiliferous Parahio beds of Spiti die out in a southeast direction.

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[1] W. A. Obrutschew. " Geologic von Siberisen Heft 15," S. 69 (1926).

[2] By Dr. L. F. Spath the Australian species " *Salterella hardmani* " has been re-christened *Biconulites hardmani* (Foord) [*Geol. Mag.*, LXXIII, p. 433 (1936)]. Another Australian species, " *Salterella planocorea* Tate " will also probably have to be included in P. T. de chardin's genus " *Biconulites*."

[3] W. B. R. King. *Pal. Ind.*, New Ser., Vol. XXII, Mem. 5, p. 3 (1937).

[4] Y. C. Sun. *Pal. Sin.* Ser. B. Vol. I, Fasc. 4, p. 15 (1924).

During the Middle Cambrian period, marked changes took place, and we are confronted with the first clearly established evidence of a world-wide marine transgression. Not only did the southern Asiatic sea encroach upon the land-mass to the north in the form of gulfs over what are now parts of the Yenisei and Lena valleys, but it extended eastwards across the Pacific to the Canadian Rocky Mountains area and the State of Utah, with an easterly arm reaching as far as Vermont and New York.[1] In Manchuria, central China, Tonkin, north India and certain parts of Siberia, there is everywhere the same conspicuous absence of *Paradoxides*, the dominating trilobite of the Atlantic province, and the presence of the primitive Asaphids so characteristic of the western portion of North America and there is little doubt that the relatively shallow seas that covered these areas in Asia were connected with that which occupied western North America. This seems to be indicated by the presence in the middle Cambrian of southeast Asia of *Asaphiscus*, *Bathyuriscus* and *Dolichometopus*. On the other hand, a European connection is suggested by the presence of *Conocoryphe*.[2] In such ways, the faunas of the Asian and Pacific Provinces lost some of their individuality and became to some extent confluent. In the cases of the Punjab and of China, individually, this relationship to western North America seems to have been a fairly close one though, curiously enough, the differences between the faunas of the Punjab and China are conspicuous. The Spiti fauna of the Punjab is much closer to that of the Rocky Mountains than to that of China, and it has been conjectured that, eastwards of Spiti there was "a more direct and uninterrupted communication with the western American sub-province than with that of the Chinese sea to the north."[3] That the connection between central China and western North America was incomplete towards the end of Middle Cambrian times is shown by the distinctive Chinese trilobites, *Damesella*, *Blackwelderia* and *Drepanura*, which, though present in Tonkin, are not found in America, while on the other hand, the American genera, *Karlia*, *Ogygopsis*, *Burlingia*, *Zacanthoides*, *Oryctocara*, *Neolenus*, and the brachiopod *Nisusia*, are absent in China. Although there is no common species between India and Indo-China, there are marked resemblances between the Middle Cambrian faunas of the two regions, exemplified by the presence of predominating *Ptychoparia*, the occurrence of the peculiar genus *Tonkinella*, and the presence of allied species of *Conocoryphe*, *Anomocare* and other genera[4] and the two regions may well have formed part of the same geo-syncline. The *Dorypyge* (*D. tenella* Whitehouse, *D. corusca* Wh. and *D. decoris* Wh. found in the upper part of the Middle Cambrian in northeast Australia has not been recorded in India. Neither the Middle nor the Upper Cambrian has been found in Yunnan.

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[1] J. W. Gregory and B. B. Barrett. "General Stratigraphy," 57 (1931).

[2] T. Kobayashi. *Rep. XVIth. Internal. Geol. Congres, Washington*, 1933.

[3] F. R. Cowper Reed. *Pal. Ind.*, Ser. XV, Vol. VII, Mem 1, 63 (1910), also *Rec.*, XL, 15-16 (1910). It has been suggested that the Himalayan geo-syncline was not directly prolonged eastwards to America but was connected with the latter region *via* the Arctic by a prolongation northwards of the Chinese gulf to coalesce with the eastern side of the Irkutsk basin. Nevertheless, the Middle Cambrian of Siberia, little known though it is, is not as close to that of northern China as might in that case have been expected.

[4] F. R. Cowper Reed. *Pal. Ind.*, New Ser., Vol. XXI, Mem. 2, p. 1 (1934).

During the Middle Cambrian period, the Atlantic province was still distinct, *Paradoxides* being unknown outside it. The sea which covered southern Europe extended eastwards, perhaps as far as the Dead Sea, though the fauna of the latter area is a highly specialised one,[1] but the strongly-marked contrast between the greater part of the Punjab fauna and the nearest European fauna would seem to point to an effective palæontological barricr forming the western boundary of the Pacific province which, however, still reached as far west as southwest Persia. On the other hand some European connection is suggested by the presence of *Conocoryphe* in Kashmir. The sea in north China became gradually shallow in late Middle and Upper Cambrian times, with the deposition of argiaceous beds and interformational conglomerates.

Assuming the identification of the plentiful form in the Upper Cambrian of Spiti as *Olenus* to have been a mistake, there is no evidence of a union during the Upper Cambrian epoch between the European sea and that of northern India. The latter still covered southwest Persia where it afforded a habitation to species of *Chuangia*; the Upper Cambrian of this region is of the order of 2,000 feet in thickness and may comprise several horizons, many of the forms being closely related to eastern Asiatic and even north American species.[2]

During the Upper Cambrian epoch, the sea of northern India probably still preserved its connection eastwards with the Pacific basin, which had grown much larger, covering the whole southern half of North America, stretching northwards as far as Alaska,[3] and westwards over north China, perhaps to the south as far as Argentina, as well as to south Australia and Tasmania.[4] The mutual distinctiveness of the Middle Cambrian faunas of China and north America disappeared in the Upper part of the period, indicating a more open communication between the two regions. The Upper Cambrian of China is essentially similar in general aspect to that of the Rocky Mountains and upper Missisippi portions of this great basin, the characteristic trilobite of which was *Dicellocephalus*. Towards the close of the Cambrian period, the connection between China and the Siberian basin seems to have become closer, and it is along this path that Grabau suggests the trilobite, *Ceratopyge*, migrated from China in Upper Cambrian times and reached western Europe by the beginning of the Ordovician.

The volcanic activity in the Bawdwin and other areas of the Shan States of Burma persisted across the Pangyun epoch into the Lower Ordovician (Pindaya). Until the age of the Vindhyan sedimentation has been more definitely determined and until more certain correlation between the Vindhyan, Kurnool, Bhima and other supposed equivalent deposits has been achieved, it would be idle to speculate to any useful extent as to what conditions prevailed over the Peninsular portion of India during Cambrian times.

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[1] W. B. R. King. *Geol. Mag.*, Vol. LX, p. 514 (1923).
[2] W. B. R. King. *Pal. Ind.*, New Ser., Vol. XXII, Mem. 5, p. 5 (1937).
[3] T. Kobayashi. *Jap. Journ. Geol. & Geogr.*, p. 40, XII (1935).
[4] F. R. Cowper Reed. *Rec.*, XL, 8 (1910).

CHAPTER XVI

ORDOVICIAN.

Distribution. **Spiti:** Character of beds; Relationships of the Fauna; Extensions southeastwards and northwestwards. **Kashmir. Kumaon.** **Ngari Khorsum (Hundes)-Tibet. Nepal. Afghanistan. Burma: The Northern Shan States;** Position; Subdivision; Ngewetaung Sandstone; Naungkangyi series; Lower Naungkangyi stage; Lower Naungkangyis in North Hsenwi; Lower Naungkangyis in the Bawdwin area; Upper Naungkangyi stage; western area. Hwe-Mawng stage, eastern area. Hwe-Mawng beds. Abundance of life in the Upper Naungkangyi epoch. The Naungkangyi fauna and its relationship; Nyaungbaw Limestone. **Southern Shan States: Pindaya Beds;** The Pindaya range; Inliers; The Taung-gyi range; Exposures further north; Exposures further south; Exposures east of Taung-gyi; Correlation. **Mawsön Series; Thitteikkon Sponge Beds. Orthoceras Beds. Yunnan. Myitkyina. Palœogeography.**

Distribution.—The Ordovician system has been definitely recognised in Kashmir, the Kangra district of the Punjab, Bashahr State and Kumaon—all parts of the Himalaya—and in the Northern and Southern Shan States of Burma, as well as the neighbouring Chinese Province of Yunnan. Possibly the period is represented in the Peninsula by some of the horizons of the Upper Vindhyan, which system has already been described.

SPITI.

Character of the Beds.—Throughout the Spiti valley, in the Kangra district of the Punjab Himalaya, the Cambrian beds are overlain by a great system of shallow-water deposits, consisting broadly of conglomerates at the base, followed by grits passing up gradually into a thick mass of red, gritty quartzite with occasional thin bands of shale, succeeded in turn by impure limestones and shales.[1] A good section is to be seen near Shian, in the Pin valley, a few miles south of the village of Muth :

(*i*) Shaly limestone, with brachiopods, gastropods and corals	about	30 feet.
(*h*) Hard, grey, dolomitic and siliceous limestone with grey and green shales	,,	40 ,,
(*g*) Dark grey limestone, weathering brown, with cystidean-like bodies above and brachiopods below . . .	,,	30 ,,
(*f*) Dark, fœtid limestone, with shaly limestone and shale bands, brachiopods and trilobites	,,	200 ,,
(*e*) Shaly and flaggy sandstones and quartzite with *Orthis* and doubtful plant remains, passing down through red and green, thin-bedded quartzites and siliceous shales into the red quartzite	,,	150 ,,
(*d*) Red, gritty quartzite	,,	1,500 ,,
(*c*) Grit and quartzite, passing down into coarse conglomerate alternating with quartzite	,,	100 ,,
(*b*) Conglomerate composed of fragments of white quartz, often angular, in a fine-grained slaty matrix . .	,,	2 ,,
(*a*) Coarse, reddish and purple conglomerate	,,	73 ,,
(Cambrian purple quartzite, with slate containing fragments of trilobites.)		

A fault separates the basal conglomerate from the Cambrian quartzite in this section, but does not affect to any extent the normal sequence, which is identical with that seen in unfaulted sections high up among the hills to the W.S.W. of Muth.

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[1] H. H. Hayden. *Mem.*, XXXVI, 20-32 (1904).

In unfaulted sections the conglomeratic beds lie unconformably upon the Cambrian and show a certain amount of variation both in character and thickness. In the Parahio valley, there are two conglomerate bands, which are separated from each other by hard sandstones and pale quartzites ranging from about 20 feet across to a mere thread and sometimes dying out altogether ; the lower band contains, in addition to pebbles of quartzite, most of which range from three to six inches in diameter, larger pebbles or boulders of Cambrian dolomite. The red quartzite, " d ", varies a little in colour but is otherwise constant in character throughout Spiti and Bashahr ; it is unfossiliferous, thick-bedded, and interbedded with thin layers of a lighter-coloured shale.

Towards the top, the red quartzite becomes more thinly bedded and is gradually replaced by the fossiliferous succession of limestones and shales enumerated above. Of these the lowest, " e ", contains impressions of *Orthis*, including :—a form found in the Niti area of Garhwal, *Orthis* (*Dinorthis*) *thakil* Salter ; a doubtful *Rafinesquina cratera* (Salter), also a Niti form ; an unidentified species of the trilobite *Lichas* ; *Pasceolus mellifluus* (Salter), a form of doubtful biological position but common to various parts of the Himalaya ; crinoid stems ; and some doubtful vegetable remains which, it has been suggested, may be branches and stems of two species of the little-known plant, *Bythotrephis*, found in the Ordovician of Tonkin and abundant in the Lower Ordovician of North America.[1]

The fœtid limestone, " f ", contains numerous fossils, chiefly trilobites and brachiopods, including[2] :—

Bryozoa—
  Dianulites yak (Salter),
  Ptilodictya (?) *ferrea* Salter.
Brachiopoda—
  Orthis (*Plectorthis*) *stracheyi*, Reed var. (?) (poorly preserved),
    ,, (*Hebertella*) cf. *sinuata* Hall or *occidentalis* Hall (two species from the Hudson River group),
    ,, (*Dalmanella*) *testudinaria* Dalman, var. *himalaica* Reed,
    ,, (*Dinorthis*) *thakil*, Reed, var. *subdivisa* Salter,
    ,, ,, ,, ,, ,, *striatocostata* (?) Salter,
    ,, ,, *porcata* McCoy, var. *peregrina* (?) Reed (*Orthis porcata* is a *variable* form found in Great Britain and America).
  Triplecia uncata (?) (Salter),
  Leptæna trachealis (Salter) (common),
  Sowerbyella himalayensis, var. *repanda* (Salter),
    ,, *umbrella* (Salter),
  Strophomena chamærops Salter (common),
    ,, (?) *bisecta* Salter,
  Rafinesquina muthensis (Reed),[3]
  Zygospira (?) sp.,
  Hindella (?) sp.

Lamellibranchiata—
  Pterinaea thanamensis Reed.

Gastropoda—
  Lophospira aff. *serrulata* (Salter)

Pteropoda—
  Cornulites sp.

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[1] Probably the remains referred to by Dr. B. Sahni as being so badly preserved that their botanical value is very doubtful (*Proc. 8th. Ind. Sci. Congr.* viii (1921)).

[2] F. R. Cowper Reed. *Pal. Ind.*, Ser. XV, Vol. VII, Mem. 2 (1912).

[3] A form comparable to this has been found in the *Orthis* bed of the Neichia formation (Llandeilo) of Central China (M. S. Chang, *Pal. Sin.*, Ser. B, Vol. I, Fasc., 3, p. 18 (1934)).

Trilobita—
Illænus punctulosus Salter (common),
,, *spitiensis* Reed,
,, *brachyoniscus* Salter,
Bronteus aff. *lunatus* Billings (common ; species found in the Trenton Limestone of America).
Asaphus emodi, var. *milamensis* Reed (common),
Lichas (*Amphilichas*) *tibetanus* Salter,
Calymene nivalis Salter (common),
Cheirurus mitis Salter (common).

Ostracoda—
Eurychilina monticuloides Reed (closely allied to species from the Trenton beds),
Krausella shianensis Reed,
Primitia everesti Reed,
,, *gerardi* Reed,
Leperditella (?) *himalaica* Reed,
Leperditia sp.,
Beyrichia sp.

Above this "trilobite limestone" is another limestone which has yielded the following few forms : a coral belonging probably to the genus *Lyopora ; Orthis* (*Plectorthis*) *stracheyi* Reed ; *Orthis* (*Dalmanella*) *testudinaria* Dalm., ? var. Reed ; *Parastrophia indica* Reed ; *Mesotrypa* sp. ; *Conradella* aff. *obliqua* Ulrich & Schofield, a gastropod very closely allied to *C. obliqua* from the Black River group of Minnesota ; the curious cystidean-like ostracod, *Apidium indicum* Reed ; and *Pasceolus shianensis* Reed, of uncertain zoological position.

Forty feet of limestone, from which no determinable fossils have been recovered intervene between the above horizon and the uppermost horizon ; in the latter the following forms have been identified :—

Actionozoa—
Streptelasma aff. *corniculum* Hall (a Trenton Limestone form),
Bryozoa—
Atactoporella sp. (allied to forms from the Trenton and Cincinnati beds of Minnesota),
Brachiopoda—
Orthis (*Dalmanella*) *testudinaria*, Dalman var.,
,, (*Dinorthis*) *porcata* McCoy var. *peregrina* Reed,
Leptæna rhomboidalis Wilckens (the persistent and cosmopolitan form which is found also in the Silurian beds of Spiti),
Strophomena aff. *wisconsinensis* Whitfield (rather abundant),
Sowerbyella sericea (?) (Sowerby) (a cosmopolitan form),
Hindella shianensis Reed.

Gastropoda—
Lophospira cf. *bicincta* (Hall) (practically indistinguishable from the Minnesotan form),
Hormotoma cf. *trentonensis* Ulrich & Scofield ?,
Bellerophon sp.
Cephalopoda—
Gonioceras cf. *anceps* Hall.[1]
Trilobita—
Illænus sp.

To the southeast, in the Thanam valley of Bashahr, occurs a shaly facies of this limestone, in which bryozoa largely replace the brachiopods, gastropods and cephalopods ; its fossils include :—a species of *Stictopora* resembling the New York form, *S. elegantula* (Hall) ; *Ptilopora* sp. ; *Rhinidictya* sp. and doubtful species of *Phylloporina* and *Favosites*.

Relationships of the fauna.—The assemblage of organisms in each of the above stratigraphical horizons is appreciably distinct. Cowper Reed remarks

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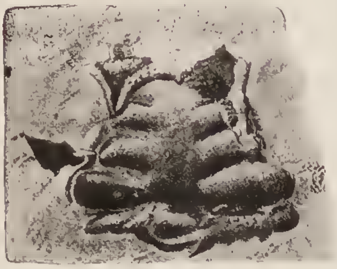
[1] T. Kobayashi suggests that this may have more in common with the genus *Lambeoceras*. *Journ. Fac. Sci. Imp. Univ. Tokyo*, III, Pt. 8, 459 (1934).



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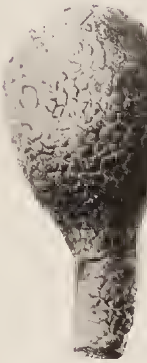

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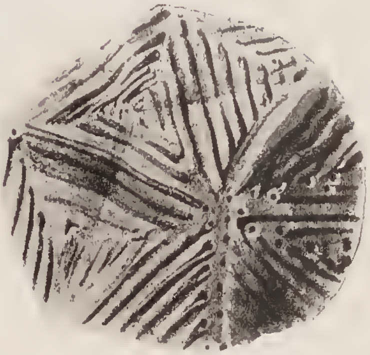

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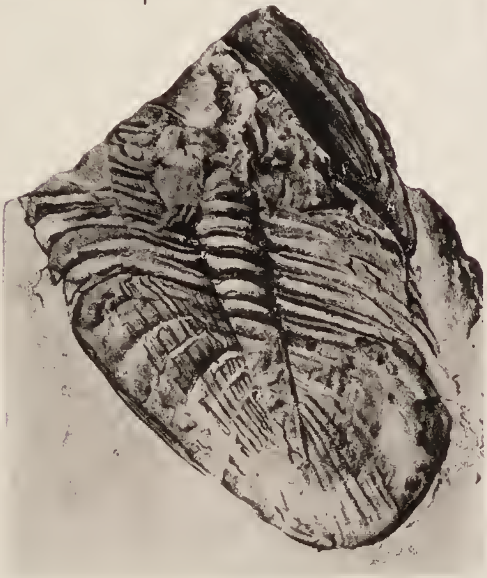

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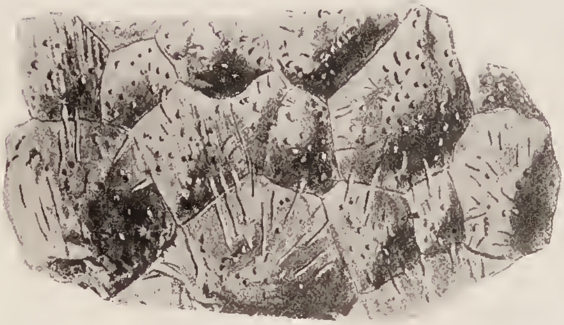

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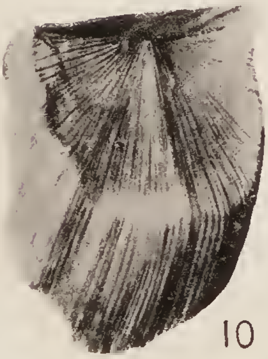

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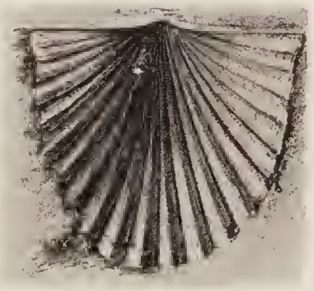

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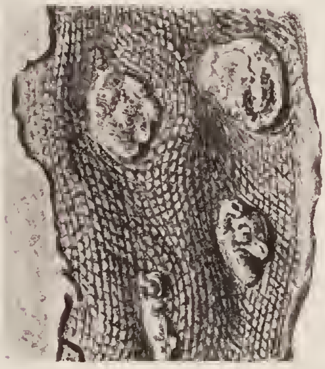

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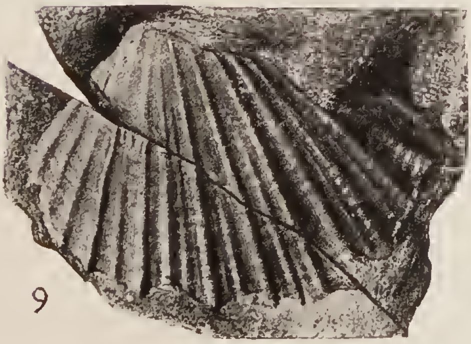

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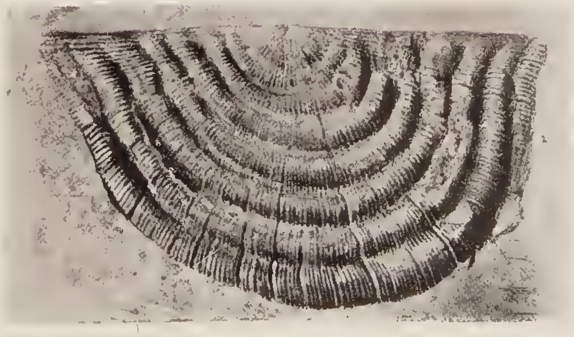

8

ORDOVICIAN FAUNA.

1. *Calymene nivalis* Salter. 2. *Ogygites birmanicus* Reed. 3. *Graptodictya griesbachi* Reed. 4. *Apidium indicum* Reed. 5. *Aristocystis dagon* Reed. 6. *Heliocrinus qualus* Reed. 7. *Orthis pustulifera* Reed. 8. *Leptaena trachealis* (Salter). 9. *Pterinea thanamensis* Reed. 10. *Rafinesquina subdeltoidea* Reed.

G. S. I., Calcutta.

that the lithological characters of the beds indicate that the differences in the faunas are not directly due to conditions of sedimentation, but suggest a true faunal series ; very few recognisable species range up from one horizon to another, except a few cosmopolitan forms which everywhere have a long range.

Regarded as a whole, the Ordovician fauna of Spiti is obviously an incomplete one and generalisations must be looked upon as provisional. As known, it is characterised by the predominance of brachiopods, several genera of which are uncommon (*Hindella*, *Parastrophia*, etc.), by the scarcity and small size of the trilobites, which are practically restricted to Horizon 2, and by the extreme rarity of mollusca. The great majority of the species are peculiar to the Himalaya, but no less than two-thirds of specifically determinable forms, though not definitely identical, show remarkably close affinities with American forms. These American relationships separate the Himalayan Ordovician fauna almost completely from that of Annam,[1] a possible exception being seen perhaps in *Calymene douvillei* from Annam, which may be a mutation of the Himalayan *C. nivalis*.[2] Equally notable is the absence of any European affinities—excluding the presence of cosmopolitan species—a trait more striking in view of the fact that the relations of the Burmese Ordovician, like those of the Chinese beds, are clearly European and not noticeably American.[3] The only Burmese element identified in the Himalayan Ordovician is the trilobite, *Pliomera*, which seems to be representod by the same species ; an allied form has been noted in Korea.[4] Although no species has been definitely identified as common to the Himalaya and America, the American stamp of the succession of faunas from the former region is unquestionable ; the small differences are attributed to "a certain amount of modification having taken place in the course of their long migration from America".

The great majority of the American allied or representative species from Spiti belong to the Chazy or Trenton formations, from which it would appear that the beds from Horizons (e) to (i) are to be correlated with the Middle Ordovician or American Mohawkian. The Lower Ordovician may well be present in the unfossiliferous horizons (a) to (d). There seem to be no representatives of Ordovician horizons higher than the Mohawkian, in spite of the fact that the beds pass up with every appearance of conformity into the Silurian. Dr. Cowper Reed notes that there may have been cessation of deposition in this area without erosion, but there is no suggestion of such local interruption in the sedimentation, and it looks as if the Middle Ordovician type of fauna had lasted on until the incoming of the Silurian.[5]

Extensions southeastwards and northwestwards.—The Ordovician varies little throughout Spiti and its outcrop passes southeastwards over the dividing range into Bashahr. It can be traced along the left side of the Thanam valley to the Hangrang Pass but is of smaller extent in this area than it is in Spiti, having been greatly eroded in Permian times ; in places the Permian beds are seen resting on the Ordovician red quartzite. To the northwest, Ordovician and Silurian beds are found at Trakse, near Losar in upper Spiti, where they are considerably crushed and faulted, but in other respects similar to the succession near Muth. From the Kunzam Pass they extend northwards along the left side of the Chandra valley, and still further into north Lahaul where traces of *Orthis* and trilobites are to be found in a light-coloured limestone.

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[1] H. Mansuy. *Mem. Serv. géol. Indo-Chine*, VII, Fasc. 1, p. 3 (1920).
[2] H. Mansuy. *Ibid.*, V. Fasc. 4 (1916).
[3] F. R. Cowper Reed. *Rec.*, XL, 24-25 (1910).
[4] T. Kobayashi. *Journ. Fac. Sci. Imp. Univ. Tokyo*, Sect. II, Vol. III, Pt. 8, 492 (1934).
[5] F. R. Cowper Reed. *Pal. Ind.*, Ser. XV, Vol. VII .Mem. 2, 167 (1912).

KASHMIR.

To the east of Islamabad in Kashmir, a thick series of pale, thin-bedded, slaty shales and fine, compacted, impure sandstones was discovered by Middlemiss beneath a thin band containing Silurian fossils. The organic remains in this "graywacke group" have proved to be so far indeterminable, but they may be considered as representing in all probability the Ordovician as well as the Cambrian.[1] These beds have already been described under the heading of Cambrian (see page 585).

In eastern Kashmir, the beds mapped by Lydekker as Panjals may possibly include representatives of the Ordovician. It is not known whether the Ordovician is present in the outcrops of Lydekker's "Panjal system" in the Ladakh range, around Pangong (Pangkong or Tso-mo Gmalari), in the Changchenmo and Shyok basins, and in the vicinity of Leh and Skardu.

Over the greater part of the older Palæozoic tract exposed between the Kishanganga and Jhelum rivers in central Kashmir, the Ordovician system, so far as is known, is unrepresented, the Upper Cambrian lying directly under the Muth Quartzite (Upper Silurian or Devonian) or still younger formations. At the centre of the Marhaum syncline of Upper Cambrian beds, however, a succession of sandy, ferruginous slates, quartzose graywackes and sandstones, occupying a small area only, was found by Mr. Wadia to yield Ordovician fossils.[2] The latter are prolific but fragmentary, including proparian trilobites and many orthid and strophomenid brachiopods. From a quartzose, gritty, crushed graywacke, Dr. Cowper Reed has identified the following which, although insufficient to fix the precise horizon, suggest the lowest beds of the Ordovician[3] :—

Orthis marhaumensis Reed,
,, of. *calligramma* Dalm.,
,, (*Nicolella* ?) sp.,
Leptelloidea (?) sp.,
Crinoid stem-joints.

A dozen miles or so to the southwest of this area is another somewhat larger patch of variegated slates and sandy and calcareous beds containing a prolific number of obliterated fossils. These beds, which are doubtfully referred to the Ordovician and may include also Silurian strata, occupy the northern limb of the Shamsh Abari syncline, and intervene as a wedge between the Upper Cambrian blue clays and the Muth Quartzite into which they appear to pass up conformably. The rocks comprise irregularly cleaved, green and grey, shaly slate or graywacke, with sandy and calcareous partings, lenticular masses of brown dolomitic limestone, and a few sandstones. They are copiously marked by yellow blotches which, though undoubtedly representing effaced organic remains, have so far yielded no determinable examples. The rocks are everywhere penetrated by large dolerite dykes, feeders of the Panjal Trap whose bedded flows tower in precipices above the Cambrian-Silurian strata.

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[1] C. S. Middlemiss, *Rec.*, XL. 211-213 (1910).

[2] *Rec.*, LXVIII, 142 (1934).

[3] *Pal. Ind.*, New Ser., Vol. XXI, Mem. 2, p. 4 (1934).

KUMAON.

Further southeastwards from the last-described area, another gap intervenes on the geological map as far as the classical Niti area of north British Garhwal. Here the " Upper Haimantas " are described as passing up into an unbroken sequence consisting principally of limestone and quartzite and which Griesbach concluded ranged from " Lower Silurian "—*i.e.* Ordovician—through " Upper Silurian " (Silurian proper) and Devonian into the middle of the Carboniferous. Several members of the succession are fossiliferous, and Griesbach seems to have assumed prematurely that the fossils indicated the presence not only of the Ordovician, but also of the Silurian (his " Upper Silurian "), Devonian and Carboniferous rocks ranging up to a quartzite which in the majority of cases seems to have been correctly identified as the Muth Quartzite. The collections of fossils from these regions have been carefully examined by Dr. Cowper Reed who found all the assemblages referable to the Ordovician. From below the Laukpya Lekh Pass were collected a specimen of *Encrinus* aff. *punctatus* and other scarcely determinable forms suggestive of a Silurian age, but, beyond these slender indications, the presence of any beds younger than the Ordovician in the particular section of the Himalaya now under consideration, although probable, does not appear to be supported by the palæontological evidence so far available.

The so-called " Lower Haimantas, " already mentioned in a previous chapter consist of a great development of conglomerates, composed of rolled and subangular fragments, among which quartz and gneiss predominate. The matrix in which are embedded these boulders, some of them of large size, is a hard, sometimes partially schistose, quartz rock, often of a deep purple colour. In the latter case, the lighter-coloured boulders of white and grey quartzite and metamorphic rock stand out conspicuously, and the conglomerate is described as identically the same as that seen in the Spiti valley and which, there is reason to believe, is the Ordovician conglomerate of Hayden. As the majority of the sections of the " Lower Haimanta " conglomerate (Dhauli Ganga, Niti, Jadh Ganga area, from Milam to the Kali river, etc.) are characterised by the same peculiar colour, it is quite possible that the " Lower Haimanta, " so called, has no separate existence but is identical with the Ordovician conglomerate. Its boundary with the Vaikrita schists, in that case, might be a thrust. At Niti, Goting and Malari, the purple quartzites and conglomerates of the group under discussion are said to rest directly upon thick-bedded granitoid gneiss, and the boundary is much affected by granite intrusions. Griesbach's general section and his interpretation thereof, (except for the inverted commas) were as follows :—

Productus beds.

. . . .

8. White quartzite (Muth Quartzite)—350-800 feet.	Upper	" Carboniferous"
7. Red Crinoid limestone—350-700 feet but with an additional underlying stage of blue-grey earthy limestone in the southeastern parts, totalling 1,200 to 1,400 feet.	Lower	
6. Dark Coral limestone—650-700 feet in the Niti area, but said to be much greater elsewhere		" Devonian."
5. Flesh-coloured and brown quartzites—1,000-1,200 feet in the Niti sections, but much greater elsewhere		" Upper Sinurian."

4. Coral limestone		" Lower Silurian."
3. Upper 2. Middle 1. Lower	" Haimanta."	(? Cambrian).

After comparing Griesbach's interpretation of the Pin valley sequence in Spiti[1] with that of Hayden[2] regarding sections in the Parahio and Pin valleys, which was founded upon more detailed work and irrefutable fossil evidence, two conclusions seem definitely permissible, it being remembered at the same time that the Pin section examined by Griesbach was probably not identical with the Pin section described by Hayden but lay on the opposite bank of the river. In the first place, Griesbach's group (4) has yielded in the Chorhoti Pass a fauna very close to that of stage (*f*) in Spiti, the " fœtid limestone " of Hayden, and including three forms from stage (*e*) just below it. We may with some reason, therefore, assign Griesbach's No. 4 group (his " Lower Silurian ") to stage (*f*) or to stages (*e*) and (*f*)—of the Spiti Ordovician. Secondly, it is impossible to overlook the lithological similarity of Griesbach's group (5) (his " Upper Silurian ") to stage (*d*) of Hayden's Spiti section. If these are equivalents, we must assume that the sequence in Kumaon has been disturbed by folding or thrusting and that group (5) lies stratigraphically under instead of above group (4) ; its fossils, which are Ordovician, are, however, mostly identical with those found in group (4), and the fauna of both groups will be considered as a whole, the mutual relationship of the two groups being left for further investigation.

Whether Griesbach's "Dark Coral limestone " (Group 6) represents any of the higher Ordovician stages of Spiti, or the " Grey limestone with well preserved corals "—the basal Silurian bed of Spiti—it is impossible to say ; it is thick enough to represent all these stages, and may well do so as there is no recorded gap in the sequence even in Spiti where the Ordovician-Silurian boundary is drawn below the first appearance of Silurian corals. It is possible, in other words, for Group (6) of the Kumaon area to embrace the uppermost three stages of the Spiti Ordovician (*g*), (*h*) and (*i*), *plus* the lowest stage of the Silurian, No. 1.

The description of Griesbach's group (7)—the " Red Crinoidal limestone "—reads not unlike stages (2) and (3) of the Spiti Silurian and, since it occurs repeatedly just below the white quartzite (Muth Quartzite), it and the latter will be considered under the heading of Silurian.

As a provisional procedure, until a re-survey of this tract is made, it is proposed to describe under the title of Ordovician the beds mapped by Griesbach as " Silurian ", both " Upper " and " Lower." This group has been traced from the Shanki stream, west of the Niti Pass in north Garhwal, as a winding or zigzagging strip with a general N.W.—S.E. strike, southeastwards as far as the Kali river, which is the western boundary of Nepal. This band-like outcrop, which is not far from the Tibetan boundary, averages about two miles in width and occasionally sends off branches ; it is at first displaced by a few small dip faults and is interrupted for six or seven miles by a large strike fault above the Milam glacier, but becomes more regular and uniform in the Almora district, where at the same time a secondary belt and small inliers in younger rocks make their appearance to the northeast.

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[1] *Mem.*, XXIII, 212 (1891).

[2] *Mem.*, XXXVI, 22, 24 (1904).

The so-called "Upper Silurian" is described as consisting of evenly-bedded, dirty pink to flesh-coloured quartzites, with greyish green, friable shales dividing them. In the Niti area, the thickness of this stage varies from 1,000 to 1,200 feet—figures comparable with the thickness (1,500 feet) of its suggested Spiti equivalent, the red quartzite. It differs from the latter, however, in possessing abundant traces of organic remains. Whatever may be its equivalents elsewhere, there is no doubt regarding its Ordovician age. Forms labelled as coming from exposures of this group in the Silakank Pass, in the Dharma Pass, in the Marchauk Pass and in the Mankshang Pass exhibit a palæontological facies which is wholly Ordovician and about which there is nothing to suggest a Silurian age.[1]

In considering the so-called "Lower Silurian", we are on just as firm ground. This is a dark limestone—described as a "coral limestone"—with many fossils which in most cases are imperfect but which in the upper horizons of the stage are often well preserved. It is said to pass down and alternate with the "Upper Haimanta," and to pass up and alternate in the same way with the flesh-coloured quartzites. However this may be, there is no question of its Ordovician age, for the facies of its fauna, like that of group (5), is wholly Ordovician. In the Niti and Milam areas, the thickness of this stage is 300 feet, and this is about the average figure in undisturbed sections elsewhere. It is well seen in the lower slopes of the Silakank peaks (19,265 feet), and a belt of it and the red quartzite forms part of the great triangular cone of Painkanda (19,340 feet), and sweeps round the northern buttresses of Dunagiri (23,184 feet).

With slight modifications in the terminology, the following is a list of forms obtained at various times and by various observers from both groups (4) and (5) and from horizons not specifically mentioned, the majority from the Chorhoti Pass.[2]

Actinozoa—
  Heliolites depauperata Salter,

Bryozoa—
  Dianulites yak Salter.
  Rhinidictya plumula (Salter) (comparable with a form in the Naungkangyi beds of Burma).
  Graptodictya griesbachi Reed.
  Lioclema indicum Reed (?).
Crinoidea—
  Crinoid stems.
Brachiopoda—
  Lingula kali Salter,
    ,, *ancyloides* Salter,
  Orthis (*Dalmanella* ?) *tibetica* Salter,
    ,, (*Dinorthis*) *thakil* Salter, var. *convexa* Salter (having strong resemblances to the British *O. flabellulum* Sow., and to the Trenton species *O. pectinella* Emmons),
  Orthis (*Dinorthis*) *thakil* Salter, var. *striatocostata* Salter,[3]
    ,, ,, ,, ,, var. *subdivisa* Salter,
    ,, ,, ,, ,, var. *trifida* Salter,
    ,, ,, *porcata* McCoy, var.,

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[1] F. R. Cowper Reed. *Pal. Ind.*, Ser. XV, Vol. VII, Mem. 2, 152 (1910).

[2] See F. R. Cowper Reed. *Pal. Ind.*, Ser. XV, Vol. VII, Mem. 2 (1910).

[3] The *striatocostata* variety also bears a strangely close resemblance to *Stropheodonta annamitica* Mansuy from Devonian beds in Tonkin ; this brachiopod was at first described as *Orthis* (*Dinorthis*) *annamitica* and appeared to be somewhat of an anachronism (see *Mem. surv, geol. Indo-Chine*, V, Fasc. 4, p. 3). A similar very close resemblance has been quoted by Mansuy between another brachiopod from the same Tonkin Devonian, *Rafinesquina orientalis*, and *R. eneatissima* Salter from the Kumaon Ordovician.

Scenidium comptum Salter,
Triplecia uncata (Salter),
Leptœna trachealis (Salter),
,, *halo* (Salter),
Strophomena chamaerops (Salter),
Rafinesquina aranea (Salter),
,, *lineatissima* (Salter),
,, (?) *nubigena* (Salter),
,, (?) *cratera* (Salter),
Plectambonites detrita (Salter),
Sowerbyella himalayensis (Salter),
,, ,, , var. *repanda* (Salter) (found also in the Naungkangyi beds of Burma),
,, ,, , var. *textilis* (Salter),
,, *umbrella* (Salter),
Christiania nux (Salter),
Rhynchotrema cf. *dentata* Hall (a Trenton Limestone species),
Lamellibranchiata—
Ctenodonta sinuosa Salter,
Cyrtodonta gerardi Reed,
,, (?) *imbricatula* Salter,
,, ,, ,, , var. *costulata* Salter,
Saffordia (?) *marchaukensis* Reed (a Hudson River group genus),
Pterinea sp.
Gastropoda—
Lophospira himalensis (Salter),
,, *pagoda* (Salter) (found also in the Middle Ordovician of southern Cho-sen),[1]
Eotomaria turbinata (Salter),
Liospira emodi (Salter) (close to *L. micula* Hall a characteristic Trenton species, and still closer to *L. decipiens* Ulrich from Minnesota),
Trochonema humifusa Salter,
Cyclonema subtersulcata Salter,
,, *rama* Salter,
Holopea (?) *varicosa* Salter,
Raphistoma himalaicum Reed (very close to *R. mutans* Koken from the Orthoceras Limestone, and to *R. katoi* Kob. and *R. corcanicum* Kob. from the Middle Ordovician of southern Cho-sen),[2]
Bellerophon ganesa Salter,
Hyolithes lineolatus (Salter),
Tentaculites sp.
Cephalopoda—
Orthoceras kemas Salter,
,, *striatissimum* Salter,
Cyrtoceras (*Ooceras*) *centrifugum* Salter,
Trocholites juliformis Salter (undoubtedly allied to *T. ammonius* Conrad, from the Trenton Limestone),
Trilobita—
Asaphus emodi Salter (not unlike *Parabasilicus yamanarii* Kob. from the Middle Ordovician of south Cho-sen),[3]
Asaphus emodi, var. *milamensis* Reed,
Illœnus brachyoniscus Salter,
,, *punctulosus* Salter,
Lichas (Amphilichas) *tibetanus* Salter (close to the Chazy species *L. minganensis* Billings),
Calymene nivalis Salter,
Sphœrexochus sp.,[4]
Cheirurus mitis Salter,
Pliomera (*Encrinurella*) *cf. insangensis* Reed (species found in Burma),
Prosopiscus mimus Salter (a peculiar form both generically and specifically ; a species of this genus has been found in the Ordovician of western Annam and named *P. cheiruroides* Mansuy).[5]

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[1] T. Koboyashi. *Journ. Fac. Sci. Imp. Univ. Tokyo*, III, Pt. 8, 365 (1934).

[2] T. Koboyashi. *Journ. Fac. Sci. Imp. Univ. Tokyo*, III, Pt. 8, 373 (1934).

[3] T. Koboyashi. *Journ. Fac. Sci. Imp. Univ. Tokyo*, III, Pt. 8, 481 (1934).

[4] Salter names the species *S. idiotes*, but the state of preservation seems to be too poor for the establishment of a species (see Cowper Reed, *Pal. Ind.*, Ser. XV, Vol. VII, Mem. 2, 105 (1912).)

[5] H. Mansuy. *Mem. Serv. géol. Indo-Chine*, VII, Fasc. 1, p. 2 (1920),

Incertae sedis—
Ischadites (?) *inosculans* (Salter),
Pasceolus mellifluus (Salter).
Plantæ—
Bythotrephis sp.

A large proportion of the Niti forms are characteristic of the fœtid limestone, horizon '(f)' in Spiti; only three species have been recognised in other Spiti horizons and these are all restricted to horizon (e). It is, therefore, to be concluded that the beds in the Niti area from which fossils have been collected belong to the lower Spiti horizons; the same conclusion may be drawn provisionally regarding most of the other fossil localities.

Southeastwards, the Niti band has been cut out by a large fault, but reappears two or three miles east of Shillong Talla, whence it has been traced southeastwards for another forty-five miles through the Bhot Mahals—*i.e.*, the eastern corner of British Garhwal—as far as the Kali river. Fossils have been obtained mostly from a tough, flaggy, impure quartzite exactly similar to one seen in the Chorhoti Pass; they consist almost entirely of Niti forms, the best known fossil localities being the Lissar and the Dharma Ganga valleys.

To this band probably belong the greenish and grey marly limestones, underlain and overlain by calcareous sandstones or quartzites, recorded by Messrs. Heim and Gansser from the neighbourhood of Garbyang in the northeast corner of the Almora district, east of the Dhauli Ganga. Both sandstones were found to be fossiliferous, the upper yielding a few of the fossils mentioned above and in addition: *Orthothetes pecten* Sow., *O. orbignyi* Dav., and *Leptæna sphærica* Jeann.[1]

NGARI KHORSUM (HUNDES), TIBET.

The "Coral limestone" and dark greenish clay-slate of the Kumaon Ordovician ("Lower Silurian") were recognised by Griesbach[2] at the top of the Tsang Chok La in Ngari Khorsum, north of the great Mana and Gangotri glaciers of Garhwal. In this pass, the beds, from which fragmentary corals were collected, occur between the red quartz shales forming the top of the "Haimanta" system and the easily recognisable dirty pink quartzite and greenish-grey shales of the so called "Silurian"; the latter are being considered provisionally in this chapter as basal Ordovician though placed by Griesbach above the "coral limestone" and called by him "Upper Silurian".

NEPAL.

On the crest of the Chandragiri Pass, few miles W.S.W. of Kathmandu, Messrs, Sutton Bowman and Auden have both collected cystids and *Orthis* from a limestone which Medlicott had suspected of being crinoidal in character. The age of the limestone must be Lower Palæozoic and is probably Ordovician. This occurrence is of unusual interest since it lies in the Lesser Himalaya, on the Indian side of the Great range.[3]

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[1] *Denkschr, d. Schweiz. Naturf. Gesells.*, Bd. LXXIII, Abh. 1, p. 121 (1939).

[2] *Mem.*, XXIII, 202 (1891).

[3] J. B. Auden. *Rec.*, LXIX, 140 (1935); "*Current Science*", III, 290, January, 1935.

AFGHANISTAN.

Some greatly indurated beds consisting of hard, dark blue slates with bands and patches of white quartzite form the Surghar hills and the main axis of the Safed Koh, of which the Surghar hills are the continuation, in eastern Afghanistan. These beds dip steeply to the north and are faulted against the Trias; they have been referred by Hayden to the older Palæozoic but their precise age is unknown.[1]

Some of the slates of the Kalu series in Afghanistan may possibly be of Ordovician age (see p. 458), but no fossils have up to the present been fonnd therein.

BURMA.

The Bawdwin Volcanic series, which, there is every reason to believe, range up into the Lower Ordovician from horizons which may possibly belong to the Cambrian, has been described in the preceding chapter, where also have been considered the Pangyun beds whose age may prove to be partly Ordovician as well as Cambrian. Fossiliferous Ordovician beds were first investigated in the Northern Shan States of Burma, whence the beds pass southwards into the Southern Shan States and northeastwards into Yunnan.

NORTHERN SHAN STATES.

Position.—The largest Ordovician outcrop in the Northern Shan States occurs east of Mandalay. This is continued northwards and then southeastwards as a narrow interrupted band separating the Chaung Magyi exposure from the Silurian or from the Devonian where the Silurian is missing. Soon the strike curves round again to a northeasterly direction, completing the curious double knee-shaped bend of the rock outcrops already noticed, past Hsipaw, opposite which the beds are exposed as inliers beneath the Silurian. East of Maymyo, a N.—S. inlier of Ordovician and Silurian occurs in the plateau of Devonian limestone—the lower portion of the Plateau Limestone formation—the Ordovician being faulted along its western margin against the Devonian. Restricted bands, disturbed by dip faults, occur along both the eastern and western margins of the Chaung Magyi inlier of Mong Tung, and around other irregular inliers of the same ancient rocks further to the northeast. A narrow band of fossiliferous Ordovician beds, passing down with apparent conformity into the Pangyun formation, continues for some thirty miles to the northeast of the Bawdwin area, approximating closely to the trend of the Chaung Magyi rocks, before finally disappearing beneath the Plateau Limestone in North Hsenwi, about latitude 23° 30′; this point, about twenty miles from the Chinese frontier, is the most northerly known occurrence in the Federated Shan States.

Subdivision.—The system has been divided by LaTouche[2] into five groups, two of which are merely local, and two others of which may be more or less mutually equivalent. By assuming the approximate equivalence of the latter the groups become reduced to four as follows:

(4) Nyaungbaw Limestone (local);
(3) Western area:—Upper Naungkangyi stage;
    Eastern area:— Hwe-Mawng Purple Shales (partly or wholly homotaxial with the Upper Naungkangyi stage);
(2) Lower Naungkangyi stage;
(1) Ngwetaung Sandstones (local).

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[1] *Mem.*, XXVIII, 106 (1900).
[2] *Mem.*, XXXIX, Pt. 2, 65-66 (1913).

Ngwetaung Sandstones.—What is thought to be the lowest group is exposed as a small outcrop about twelve miles east of Mandalay on the hill known as Ngwetaung, of which it forms the crest and western slope. On the west, it is faulted against Devonian ("Plateau") limestones ; eastwards, it passes under the Naungkangyis. The beds consist of coarse to fine-grained, brown sandstones, sometimes enclosing thin lenticular bands of limestone. Scattered fragments of crinoid stems and a few ill preserved specimens of a small *Orthis*, thought to be *O*. (*Dalmanella*) *testudinaria* Dalman, are recorded by LaTouche. Possibly the Ngwetaung Sandstones are represented farther to the north, near Taung-gaung, and also on the southern slopes of the Loi-len range east of Lashio. In the former locality they appear to be unfossiliferous, but in the latter one or two specimens of *Orthis testudinaria* have been found.

Naungkangyi Series.—The Naungkangyi series has yielded many characteristic Ordovician fossils and has been divided provisionally by LaTouche into an upper and a lower stage. Further subdivision will be possible when it is known to what extent the somewhat marked local differences in the fauna are due to inadequate fossil-collecting, to contemporaneous variation in conditions of deposition, or to difference in horizon. Generally speaking, the brachiopods show a preference for calcareous sandy beds and the cystideans and trilobites for argillaceous deposits. Nevertheless, trilobites occur in large numbers also in the sandy beds, though always in fragments. The bands of limestone in the shale are to a large extent composed of crinoid ossicles and are in fact little more than a cemented crinoid sand. These Ordovician seas evidently possessed an exceedingly rich crinoid fauna of which these ossicles are the only relics.

Lower Naungkangyi Stage.—The more westerly outcrops of the Lower Naungkangyi stage are composed of yellow or buff-coloured sandy marls with strong lenticular bands of coarsely crystalline limestone, all containing fossils. The marls, when excavated to a sufficient depth, sometimes pass into solid limestone, and may very possibly be the remains of limestones from which most of the calcareous matter has been leached out by weathering. In the eastern ranges, around Mong Tung, near Mong Yai, east of Lashio, and to the north of the Nam Yao valley, limestone is entirely absent, the rocks consisting of homogeneous, yellow or buff-coloured, soft, sandy marl, from which friable casts of fossils can with difficulty be collected intact. The dip is apt to be high and both beds and fossils are usually crushed and distorted, but the band, though not commonly exceeding 200-300 feet across, is surprisingly persistent. From the various exposures of this Lower stage the following assemblage has been obtained[1] :—

Cystidea—
(n) (s) *Aristocystis dagon* Bather (this genus is known in the Upper Ordovician of Bohemia),
(n) (s) *Heliocrinus fiscella* Bather (this genus and that of *Protocrinus* are especially characteristic of the Lower Ordovician of northern Europe),
(n) (s) *Heliocrinus rugatus* Bather,
(n) (s) ,, *qualus* Bather,
Echinoencrinus aff. *senckenbergi* H. v. Meyer (species found in the Lower Ordovician of north Europe),
Cheirocrinus (?) sp.
(n) (s) *Caryocrinus turbo* Bather,
(n) (s) ,, *avellana* Bather,
(n) (s) ,, *aurora* Bather,
(n) (s) *Protocrinus sparsiporus* Bather,
Crinoid ossicles in abundance.

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[1] F. R. Cowper Reed, *Pal. Ind.*, New Ser., Vol. II, Mem. 3 (1906) ; Vol. VI, Mem. 1, 1-58 (1915).

Bryozoa—
Escharopora sp. (one of the forms from Niti probably belongs to this genus but not to the same species),
Rhinidictya cf. *plumula* Salter (found in the Ordovician of Niti),
(n) *Graptodictya birmanica* Reed (allied to *G. proava* (Eichwald) of the Baltic provinces),
(n) *Phylloporina orientalis* Reed,
(n) (s) *Diplotrypa* (*Mesotrypa* ?) *sedavensis* Reed (resembling two Trenton Limestone forms),
(s) *Fistulipora* sp.

Brachiopoda—
(s) *Schizotreta* cf. *elliptica* Kutorga (found in the Ordovician of Russia),
(s) *Rafinesquina imbrex* Pander (typical of the Lower Ordovician of northern Europe and found also in America ; this species is much the same as *R. lineatissima* from Niti),
(n) *Rafinesquina subdeltoidea* Reed (close to *R. deltoidea* from Russia),
(n) *Sowerbyella ledetensis* Reed ("*Leptœna ledetensis*"),
Sowerbyella quinquecostata (McCoy) (found in the British Isles, Russia and Australia, allied to *S. himlayensis* from Niti),
Sowerbyella sericea (Sow.) (a species well known in the British Ordovician, and found also in China and in Australia),
Orthis calligramma Dalman (found in Britain, China, Siberia and elsewhere ; the commonest fossil in the Kiau-tshang-pa Limestone)[1],
,, (*Dalmanella*) *testudinaria* Dalman (a cosmopolitan form),
,, ,, *elegantula* Dalman (a cosmopolitan form),
(n) ,, (*Dalmanella ?*) *chaungzonensis* Reed (an abundant form, with considerable resemblances to *O. thakil* var. *subdivisa* from Niti),
,, (*Dinorthis*) *flabellulum* Sowerby (typical of the Bala series, especially of the Middle Bala of Europe),
(n) ,, *irravadica* Reed (closely allied to *O. moneta* Eichw. from the Russian Ordovician),
(n) ,, *subcrateroides* Reed,
(s) *Clitambonites* cf. *pyron* Eichw. (occurs in the Echinosphærite Limestone of the Baltic provinces),
Clitambonites cf. *squamata* Pahlen (occurs in the Echinosphærite Limestone ; a similar form is also found in the Ordovician east of Nankin),
(s) *Porambonites intercedens* Pander (found in Russia and Southern Shan-si).

Lamellibranchiata—
(n) *Modiolopsis thebawi* Reed (closely allied to *M. reedi* Kob. from the Middle Ordovician of southern Cho-sen),
(n) *Ctenodonta shanensis* Reed.

Gastropoda—
Eotomaria sp.

Cephalopoda—
Trocholites sp.

Trilobita—
(n) *Calymene birmanica* Reed (closely resembling *C. parvifrons*, var. *murchisoni* Salt from the Lower Ordovician of England, and in some respects *C. nivalis* from Niti),
(n) *Calymene oldhami* Reed,
Remopleurides sp.,
Asaphus cf. *devexus* Eichw. (species found in the Baltic Provinces),
Megalaspis sp.
(n) *Cheirurus dravidicus* Reed.

Incertæ sedis—
Cyclocrinus cf. *spasski* Eichw. (species found in the Ordovician of Russia).

(n)=Species new at the time of their determination
(s)=Found at Sedaw

The rocks at the different localities vary in lithological character, and in many cases particular organic forms are restricted to one locality ; it is, therefore, extremely difficult to correlate the many scattered occurrences. One of the most prolific fossil localities is that of Chaungzon, near the railway-line west of Gokteik where the facies of the fauna is particularly rich in specimens of *Orthis*. At Sedaw , on the railway-line between Mandalay and Maymyo, the fossils weather out as hard limestone nodules from a thick band of papery shales which have been met with nowhere else. The commonest fossil of this locality is the bryozoan *Diplotrypa*, and most of the cystideans enumerated above also occur ; this rich cystidean fauna is not known elsewhere except at Shih-tien in western Yunnan.

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[1] T. Kobayashi has named the oriental varieties of this form, "*Orthis nipponica*". *Journ. Fac. Sci., Imp. Univ. Tokyo*, III, Pt. 8, 339 (1934).

The Lower Naungkangyi stage rests in most cases unconformably upon the unfossiliferous Chaung Magyi series, generally without basal conglomerate or sandstone. LaTouche suggested that the direction in which land lay was in all probability to the west and northwest—a conclusion he thought deducible from : (i) the thickening of the Naungkangyi sediments in that direction ; (ii) the presence of the Ngwetaung Sandstones at their base here ; and (iii) the absence of sedimentary deposits throughout the whole of the Palæozoic and Mesozoic periods over the large area of crystalline rocks northwest and north of the Shan States. The evidence supporting this conjecture, however, is capable of a modified interpretation, and it is probable that land lay at no very great distance both to the east and to the west ; all that can be concluded with some degree of certainty is that the Naungkangyi sediments were deposited in an open sea of uniform depth, with no land in the immediate neighbourhood.

Lower Naungkangyis in North Hsenwi..—In the western half of North Hsenwi, the Pangyun beds are seen passing up with every appearance of conformity into fossiliferous Naungkangyi sediments consisting of greenish grey, sandy shales and fine-grained, buff sandstones. Among the fossils have been recognised : *Calymene birmanica*, *Orthis* (*Dalmanella*) *testudinaria* and *Aristocystis dagon.* The equivalent of the next succeeding formation, the Namhsim Sandstone (Silurian), is present as a thin but continuous band between the Naungkangyis and the Plateau Limestone, except at the extreme northeastern termination of the belt of lower Palæozoic outcrops, where the Ordovician beds are overlain directly by the Plateau Limestone.[1]

Ordovician rocks have been recorded by Dr. M. R. Sahni[2] along the axis of a dome-shaped inlier which includes also unfossiliferous beds presumed to be of Silurian age, some six miles S.S.W. of Kutkai in North Hsenwi. The older series consists of yellowish brown sandstones and lenticular bands of limestone containing an assemblage of fossils suggestive of a Lower Naungkangyi age and including : *Rafinesquina imbrex*, *Aristocystis dagon*, *Orthis* sp., and *Cyathophyllum* (?) sp..

Lower Naungkangyis in the Bawdwin area.—In the Bawdwin area also the Pangyun series passes up conformably into the Naungkangyis which border the former in a N.-S. belt along its eastern boundary ; northwards, this belt thins out and disappears below the overlying Plateau Limestone, to reappear after a short interval, striking to the northeast. The beds include typical yellowish and reddish brown marls crowded with fossils—cystidean plates and *Rafinesquina* being the commonest—massive reddish purple sandstones with ripple-markings, bleached brown marls with *Strophomena* and other fossils, and characteristic pink mudstones crowded with brachiopods, cystid plates, crinoid stems and bryozoa.[3]

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[1] *Gen. Rep. Rec.*, LXV, 87 (1931).

[2] *Rec.*, LXVII, 45 (1933).

[3] J. Coggin Brown. *Rec.*, XLVIII, 150 (1917).

Upper Naungkangyi stage.—The Upper Naungkangyi stage is much more widely distributed than the Lower, and presents two lithological varieties, one comprising all beds of this age west of Lashio, fringing the eastern and southern borders of the old Chaung Magyi land surface, the other predominating in the eastern ranges. The western type consists of peculiar argillaceous shales and claystones often resembling lithomarge in texture and presenting a great variety of colours ranging from red, through lavender, orange and yellow, to pure white. The beds show evidence of intense crushing which has produced a kind of incipient cleavage, and has distorted the fossils. East of the Gokteik gorge, the topmost bed is a thin band of claystone of a conspicuous, dark purple colour, often passing laterally into phacoidal, argillaceous limestone ; this band is only a few feet thick but very persistent over a wide area and is not known west of the gorge. The eastern type consists of similar purple claystones ; these are the Hwe-Mawng beds mentioned above. Trilobites have been found in the Hwe-Mawng beds identical with trilobites occurring in the variegated shales of the western type, below the thin purple band of that region, so that the Hwe-Mawng purple claystones appear to be a facies of the Upper Naungkangyi variegated shales with which they must have been, to some extent at least, contemporaneous. The following fossils have been obtained from the two types :[1]

UPPER NAUNGKANGYI STAGE, WESTERN AREA

Cystidea—
  Heliocrinus sp.,
  Echinoencrinus cf. *angulosus* Pander [found in the Vaginatenkalk (Lower Ordovician) of Petrograd].
    ,, aff. *senckenbergi* E. v. Meyer (species found in the Lower Ordovician of northern Europe),
  Caryocrinus cf. *aurora* Bather (a Lower Naungkangyi species).

Bryozoa—
  Phylloporina sp. (differing from the Lower Naungkangyi species),
  Ptilodictya sp.,
  Rhinidictya cf. *plumula* Salter (a Lower Naungkangyi species, found also in the Ordovician of Niti),
  Coeloclema (?) *perplexum* Reed (a genus found in the Ordovician and Silurian of the Baltic provinces),
  Ceramopora sp. (allied to *C. spongiosa* Bassler from Esthonia),
  Rhopalonaria asiatica Reed.
Brachiopoda—
  Lingula cf. *attenuata* Sowerby (species found in the Lower Ordovician of Great Britain and in the Orthoceras Limestone of the Baltic region),
  Rafinesquina subdeltoidea Reed (a Lower Naungkangyi form),
  Sowerbyella ledetensis (Reed) (a Lower Naungkangyi form),
    ,, *quinquecostata* McCoy (a Lower Naungkangyi form),
    ,, *sericea* Sowerby (a Lower Naungkangyi form),
  Leptelloidea aff. *llandeiloensis* (Dav.) (probably identical with *Chonetoidea* (*Aegtria*) *yeostnensis* Reed, from the Pindaya beds of the S. Shan States),
  Orthis (*Dalmanella*) *testudinaria* Dalman, var. *shanensis* Reed,
    ,, (*Dinorthis*) *porcata* McCoy, var. *birmanica* Reed,
    ,, ,, *flabellulum* Sow. (a Lower Naungkangyi form),
    ,, *irravadica* Reed (a Lower Naungkangyi form),
    ,, *calligramma* Dalm., aff. var. *sowerbyana* Dav. (distinct from the Lower Naungkangyi form),
    ,, (*Platystrophia*) *biforata* (Schloth.), var. ? (a European species),
  Clitambonites cf. *squamata* Pander (a Lower Naungkangyi form),
  Strophomena sp.,
  (n) *Porambonites sinuatus* Reed (resembling P. *bröggeri* Lamansky from the lower Ordovician of Russia).

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[1] F. R. Cowper Reed. *Pal. Ind.*, New Ser., Vol. VI, Mem. I, 62-65 (1915).

- Lamellibranchiata—
  - *Shanina vlastoides* Reed (a new genus),
- Gastropoda—
  - *Maclurites* sp.[1]
- Pteropoda—
  - (n) *Hyolithes* (*Orthotheca*) *irravadicus* Reed
  - (n) ,, ,, *loczyi* Reed.
- Trilobita—
  - *Remopleurides* sp.,
  - *Encrinurus* sp.,
  - (n) *Calymene birmanica* Reed (a Lower Naungkangyi form),
  - *Pliomera* (*Encrinurella*) *insangensis* Reed (the commonest trilobite in the Upper Naungkangyis ; the pygidia are found in Niti),
  - *Sphærocoryphe* sp.,
  - *Agnostus* cf. *glabratus* Angelin (species found in the Orthoceras Limestone of Sweden),
  - *Ampyx* aff. *macallumi* Salter (a British species),
  - *Harpes* aff. *flanagani* Portl. (a British species),
  - *Ptychopyge* ? sp. (allied to three Baltic species),
  - (n) *Illænus liluensis* Reed,
  - (n) *Holometopus wimani* Reed (allied to a Scandinavian form),
  - *Lichas* (*Metopolichas*) aff. *verrucosus* Eichw. (species found in the eastern Baltic), spp.
  - (n) *Calymene* (*Pharostoma*) *liluensis* Reed (allied to *C. nieskowskii* Schmid from the Baltic provinces),
  - *Cheirurus submitis* Reed (allied to *C. mitis* Salter of the Himalayan Ordovician),
  - (n) *Phacops* (*Pterygometopus*) *dagon* Reed (resembling *P. sclerops* Dalman from the eastern Baltic ; genus strictly confined to the Ordovician).
- Cephalopoda—
  - *Turrilites* sp.
- Ostracoda—
  - *Primitia* aff. *mundula* Jones (a widespread form),
  - *Krausella* sp. (much resembling *K. arcuata* Ulrich, a Trenton form).

HWE-MAWNG STAGE, EASTERN AREA.

- Bryozoa—
  - *Ptilodictya* sp. (same species as in the western area),
- Brachiopoda—
  - *Orthis* (*Dalmanella*) *testudinaria*, var. *shanensis* Reed (found also in the western area)
  - ,, *subcrateroides* Reed (a Lower Naungkangyi form).
  - *Stropheodonta* aff. *corrugatella* (Dav.) (species found in Tyrone).
  - *Sowerbyella sericea* Sow. var. (species found in western area).
  - *Christiania tenuicincta* (McCoy) (a British form).
- Lamellibranchiata—
  - *Shanina vlastoides* Reed (found also in the western area).
- Pteropoda—
  - (n) *Hyolithes clivei* Reed (resembling several European species),
  - ,, (*Orthotheca*) *loczyi* Reed (found also in the western area),
  - ,, ,, *advena* Reed,
- Gastropoda—
  - *Platyceras yulei* Reed (closely resembling *P. canaliculatum* Lindstr. from the Orthoceras Limestone of the Baltic region),
  - *Bellerophon* (*Sinuites*) sp.
- Nautiloidea—
  - *Trocholites* cf. *remelei* Schroder. (a European species.)
- Trilobita—
  - *Ampyx rostratus* Sars, var. *shanensis* Reed (much resembling a form from Waterford),
  - *Dionide hybrida* Reed(very like *D. formosa* Barrande from the Ordovician of eastern Yunnan).
  - *Asaphus* cf. *ornatus* Pomp. (a Baltic province's species),
  - *Ogygites birmanicus* Reed (Mr. Y. C. Sun has re-named this *Birmanites birmanicus*.[2]
  - *Ptychopyge thebawi* Reed (resembling *Pt. lawrowi* (Schmidt) and others from the Baltic Ordovician),
  - *Ptychoyge titanica* Reed (comparable with the eastern Baltic *Pt. plautini*, Schmidt).
  - *Megalaspis* aff. *hyorhina* H. V. Leucht. (an Eastern Baltic species),
  - *Illænus* aff. *portlocki* Salt. (a British species),
  - *Holometopus orientalis* Reed,
  - *Calymene birmanica* Reed (a Lower Naungkangyi form, and found in the Upper Naungkangyi of the western area),
  - *Phacops* (*Pterygometopus*) *dagon*, var. *wynnei* Reed (found also in the western area),
  - (*Chasmops*) sp.,
  - *Pliomera* (*Encrinurella*) *insangensis* Reed (found also in the western area and at Niti).

(n)=species new at the time of its determination.

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[1] See F. R. Cowper Reed. *Rec.*, LXV, 438 (1931).

[2] *Pal.*, *Sin.*, *Ser.* 6, Vol. III, Fasc. 1, P. 6 (1939),

In the large outcrop west of Maymyo, dips are high in the south where the Upper Naungkangyis have probably been subjected to minor folding and contortion between the more competent strata above and below; in the Memauk scarp, sixteen miles north of Maymyo, some idea of the true thickness may be obtained and this is estimated at between 700 and 1,000 feet.[1] Along the eastern margin of this outcrop a thin interrupted band of Silurian (Zebingyi beds) intervenes between the Upper Naungkangyis and the Devonian Plateau Limestone in the southern part of the area, but farther north the Ordovician and Devonian are in contact. The Upper Naungkangyi stage is well exposed in the Nam Tu valley.

Hwe-Mawng Beds.—The Hwe-Mawng purple claystones contain fossils similar to those found in the Upper Naungkangyis, including the ubiquitous *Pliomera insangensis.* The rocks are seldom calcareous but show a concretionary tendency; bedding-planes are frequently indecipherable, the fracture of the rocks being almost conchoidal. In the Loilen range east of Lashio, these purple beds accompany the band of Lower Naungkangyis, and are so intensely crushed as to resemble a schist in places. East of the Man-se-le coalfield, this phase is again exposed in great thickness in a broad dome and underlies both Silurian and Devonian; the beds are full of crinoid fragments and detached trilobite eyes, but no well-preserved fossils have been found. Along the southeastern base of Loi Ling, a thinner band of Hwe-Mawng beds rests directly upon the Chaung Magyi rocks, the Lower Naungkangyi stage being overlapped or absent. This purple stage covers a wide area among the hills east of Möng Yai, and again farther east overlooking the Nam Pang valley; thrown into numerous folds, it accompanies the thin band of Lower Naungkangyis along the eastern side of the Loi Pan and Loi Twang range in Möng Tung, where it has been laterally shifted by dip faults. A smaller patch of these beds on the western flank of this range separates the Chaung Magyi rocks from the Devonian.

Abundance of life in the Upper Naungkangyi epoch.—With regard to the fauna, the number of individual organisms that flourished in the seas of the Upper Naungkangyi period must have been extraordinary. La Touche remarks that even a small piece of the rock is seldom broken without exposing at least the stem-joint of a crinoid or cystidean, or detached calyx plates of the latter. Beautifully preserved casts occur but in a very soft and friable condition. In some places detached eyes of trilobites are abundant.

Some seven species, roughly 25 per cent., of the Hwe-Mawng forms, occur also in the Upper Naungkangyi stage of the west, but the former include a large number of peculiar trilobites, especially of asaphids which are described as allied to Lower Ordovician species.

The close faunal relationship between the Upper Naungkangyis of the west and the Hwe-Mawngs of the east is exhibited more in the general facies than in the community of a large number of species, though the limits of both may not be precisely homotaxial. At present it is impossible to decide how much the difference in the faunas is due to different environment and how much to difference in age, but the latter is probably very small.

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[1] T. H. D. La Touche. *Mem.*, XXXIX Pt. 2, 88 (1913).

The Naungkangyi fauna and its relationships.—The Pindaya beds of the Southern Shan States, which are described below, have been referred to as Naungkangyis and their faunas as Naungkangyi faunas, but it is admitted that comparatively few of the same species occur in both the Northern and the Southern Shan States. The lithology of the southern of the two sets of beds is much the same and we may, if we choose, use the term Naungkangyi for both areas, in the way we use the term Plateau Limestone for a later formation, *i.e.*, for a uniform series, which includes fossiliferous horizons varying considerably in age. Until the survey is more complete, however, it will be more convenient in this work to restrict the term Naungkangyi to the Northern Shan States beds and the term Pindaya to outcrops in the Southern States; the Pindaya faunas, as we shall see, have been referred to as belonging to the Upper rather than to the Middle Ordovician, while the Naungkangyi faunas of the Northern Shan States were originally considered to indicate a Lower Ordovician age, though some authorities would prefer to place the Lower Naungkangyis in the early Middle (Llandeilo) and the Upper Naungkangyis in the earliest Upper Ordovician (Lower Caradoc).[1] There is thus some divergence of view regarding the precise stratigraphical position of the Naungkangyis and, until the additional large collections of Burmese Ordovician fossils lying in Calcutta have been examined and the results of further field work published, the answer to the question must be postponed, but the chances are that the bulk of the Naungkangyis belong to the Middle Ordovician, corresponding approximately to the Vaginatus Limestone and Echinosphærite Limestone of Russia on the one hand, and to the Llanvirn and Llandeilo of England on the other.

The affinities and facies of the Northern Shan States Ordovician faunas are unmistakably those of the Baltic provinces of northern Europe—the "Atlantic Province" of Grabau—and not of America. This applies to all stages including the Hwe-Mawng beds, the only slight variation being that the last-mentioned stage lacks the admixture of Bohemian types of cystideans and any trace of American affinities. The fauna from the limestones at Sedaw and Palin offers the most convincing evidence, the presence of the species *Lingula* cf. *quadrata*, *Schizotreta* cf. *elliptica*, *Clitambonites* cf. *pyron*, *Porambonites intercedens*, *Rafinesquina imbrex*, and of the genera *Heliocrinus* and *Protocrinus*, suggesting the Cystidean or Echinosphærite Limestone of Scandinavia and the Baltic.

To the fauna of western Yunnan the Naungkangyi shows certain resemblances but the whole of the Naungkangyi, both lower and upper subdivisions, differs from the fauna of the Kumaon Ordovician, not only in its relationships but still more strikingly in composition. Cystidea, so extraordinarily abundant in the Burmese fauna, have not been found at all in the Himalayan; trilobites also are plentiful in the former but scarce and of small size in the latter. In bryozoa, in corals and especially in molluscs, the Himalayan has the advantage. In the brachiopoda only are points of resemblance to be found, but the genera and species common to the two areas are only those which have a world-wide distribution. It is remarkable that, as in the Himalayan region, no higher Ordovician is present in these Northern States, and that no stratigraphical hiatus seems to accompany the palæontological gap between what appears to be the Middle Ordovician and the overlying Silurian. The differences between the Naungkangyi fauna and the faunas from Tonkin and Sze-chuan are not fundamental and are insufficient to hide the common "Baltic" characters shared by the Shan States, Indo-China and central and western Sze-chuan. Of the Ordovician of Annam, which exhibits practically no relationship to that of Southwestern Yunnan, one horizon shows distant but appreciable affinities with certain horizons in the western parts of the Northern Shan States.[1] The recent discovery in the Southern Shan States of two new species of the trilobite genus *Annamitella*, hitherto known only from Annam, furnishes another link between the Ordovician faunas of the two regions. The relationship, as evidenced by the number of both allied and identical species, between Burma and the Baltic provinces of north Europe seems to have been closer even than that between the central Himalaya, Kumaon and America.

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[1] F.R.C. Reed. *Pal. Ind.*, New Ser., Vol. II. Mem. 3, p. 85 (1906) *Ibid.*, Vol. XXI. Mem. 3, p. 1204 (1936); A. W. Grabau. "The Stratigraphy of China". Vol. I, P.52 (1924).

Nyaungbaw Limestone.—Two outcrops of the Nyaungbaw Limestone stage, whose fossil contents are very meagre, are seen in the neighbourhood of Nyaungbaw village, beside the cart-road between Mandalay and Maymyo. The limestone is for the most part red or chocolate-brown in colour, passing into grey or bright blue and sometimes into purple. Interbedded with this rock are subordinate bands of red clay. The limestone bands themselves usually contain a large amount of argillaceous matter, and exhibit a peculiar lenticular structure typical of similar calcareous bands in the purple claystone at the top of the Upper Naungkangyis. Patches of the Nyaungbaw stage have been noted among the hills north of Maymyo, forming a line of conspicuous ridges near Palin. Farther east it has not been identified, unless the purple band at the top of the Upper Naungkangyis and the youngest horizons of Hwe-Mawng beds are to be considered as its representatives.

The Nyaungbaw Limestone is overlain unconformably by the Zebingyi beds (uppermost Silurian) and has yielded the following remains :—

Scyphocrinus sp. (a calyx, ossicles and stem-joints),
Camarocrinus asiaticus Reed,
Diplotrypa palinensis Reed,
Lingula cf. *quadrata* Eichw. (found in the Ordovician of Russia and Scotland),
Sowerbyella himalayensis (Sal.), var. *repanda* (Salt). (a Niti form, found also in Tonkin),
Orthis irravadica Reed (a Lower Naungkangyi form),
Orthoceras sp. (common).

The *Scyphocrinus* is undoubtedly close to *S. excavatus* Waagen and Jahu from the Silurian of Bohemia [Barrande's "Upper Silurian, stages E(e^1-e^2)"]. The peculiar *Camarocrinus asiaticus*, believed to be a float of the crinoid, *Scyphocrinus*,[2] resembles very closely "*C. ulrichi*" Schuch. from the Lower Helderbergian of the United States (late Silurian or early Devonian). Several species of *Camarocrinus* are found in the Helderbergian group of West Virginia, corresponding to Barrande's stage F, which may include Silurian horizons but, for the greater part, is now regarded as Devonian. In Bohemia a similar fossil, known as *Lobolithus*, occurs, but at a lower horizon, *viz.* stage "Ee^1", *i.e.*, in the Silurian ; this may also be a part of *Scyphocrinus*. "*Lobolithus*" and *Scyphocrinus* are found together in Bohemia, while "*Camarocrinus*" and *Scyphocrinus* are found together in Nyaungbaw.

The evidence derived from this small assemblage of fossils as to the age of the Nyaungbaw beds is in itself inconclusive. From their stratigraphical position, and especially from the unconformity—which must embrace at least the Namhsim series (a portion of the Upper Silurian)—between them and the Zebingyi series, La Touche placed these beds provisionally at the top of the Ordovician. Grabau, on the other hand, has pointed out that the genus, *Camarocrinus*, in America is first known in the uppermost Silurian (Manlius beds), though found in the Lower Silurian of Bohemia, and suggests that the Nyaungbaw may represent the Upper Silurian (Monroan of America).[1] Recently, the discovery in Yunnan of a more abundant fauna, including *Camarocrinus*, makes it probable that the Nyaungbaws are represented in the province. For the present, we may assume provisionally that the Nyaungbaw beds correspond to some part of the Ashgillian, where La Touche originally placed them.

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[1] M. Mansuy, *Mem, Serv. geol. Indo-chine*, Vol. VII, Fasc. 1, p. 3 (1920).

[2] Bassler. *Proc. U S. Nat. Mus.*, XLVI, 57-59 (1913) ; F. R. Cowper Reed. *Rec.*, XLIII, 335 1913)

SOUTHERN SHAN STATES.

Ordovician rocks have been recognised in the Southern Shan States, but their outcrops have only recently been joined up with those of the Northern Shan States. They have been preliminarily described under the terms, "Pindaya" and "Mawsön," two series whose limits have not yet been satisfactorily defined.

PINDAYA BEDS.

Pindaya Range.—Rising from dissected, rugged country to the northwest of Poila (Pwela), is the wall-like escarpment of the Pindaya (Pangtara) ridge which extends from north to south and separates the Zawgyi Chaung from the Panlaung river. Northwards, the range increases in size, attaining a height of over 6,000 feet above sea-level and becoming comparable with the Taung-gyi escarpment some miles to the east. The greater portion of the range forms an Ordovician inlier in the Plateau Limestone, but between these two formations, along the southern and western rims of the former, is an intervening narrow band of carbonaceous Silurian with a rich graptolite fauna.[2]

Proceeding westwards from the Zawgyi basin, the Pindaya beds appear to be underlain by limestones and siltstones which occupy a well-defined hilly belt and are succeeded westwards by the mountainous tract of the Chaung Magyi rocks on which they lie. These limestones and siltstones have been referred to another Ordovician formation known as the Mawsön series by Mr. V. P. Sondhi[3] who, in a traverse eastwards and along other sections also, has found the Pindaya beds succeeding the same series. Some small inliers of the Pindaya beds have been noted to the east of the main outcrop, and another outcrop has been mapped about sixteen miles north of Yawng Hwe, adjoining a Silurian inlier in the alluvium and Plateau Limestone.

The rocks are composed of calcareous shales, purple shales, mudstones and argillaceous limestone bands, the last predominating towards the top of the Pindaya range. The commonest variety of the limestone is massive, bluish grey in colour, calcite-veined, with patches and seams of argillaceous material, and often contains greatly-contorted marly bands. The shales, slates and mudstones are more frequent in the southerly portions of the exposure. In places, copper-staining has been noticed on the rocks. Near latitude 21°N., where the outcrop is about six miles across from east to west, there are interbedded rhyolites, very decomposed but occasionally exhibiting a banded flow-structure; these lavas are characterised by reddish brown and orange spots produced by the decomposition of pyrite.

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[1] "Stratigraphy of China" Vol. 1, 123, (1924).
[2] J. Coggin Brown and V. P. Sondhi, *Rec.*, LXVII, 212 (1933).
[3] *Rec.*, LXXI, 64 (1936).

The structure in this area is that of an anticlinal fold pitching southwards and itself corrugated by acute minor structures. The rocks form a characteristic light brown soil and the limestone bands are occupied by an intricate system of innumerable small cauldron valleys.

Lithologically, the rocks are comparable with the yellow and buff sandy marls and hard lenticular bands of limestone of the Lower Naungkangyis of the Northern Shan States, sixty miles to the north, but the fauna they contain indicates an Upper rather than Middle Ordovician age. Badly preserved and unidentifiable fossils are sometimes visible on the weathered surfaces of the Pindaya limestones, but from a collection made in the neighbourhood of Ye-o-sin the following forms have been determined by Dr. Cowper Reed.[1]

Hydrozoa.—
Stromatocerium cf. *huronense* Bill. (allied to *S. regulatum* Endo, from the Upper Ordovician of Manchuria).

Actinozoa.—
Streptelasma sp. (much like *Str. dispandum* Foerste, from the Upper Ordovician of Indiana).

Cystidea.—
(*s.y.*) *Sphœronis shihtienensis* Reed,
(*y.*) *Pyrocystis* (?) *orientalis* Reed.
Echinoencrinus sp.,
Heliocrinus cf. *granatus* (Wahl) (*H. granatus* is a Bala form),
(*s.y.*) ,, *fiscella* Bather,
(*s.*) *Caryocrinus* cf. *turbo* Bather.

Bryozoa.—
Chasmatopora sp.,
Rhinidictya cf. *nitidula* (Billings) (may be identical with one or other of the Naungkangyi forms),
,, cf. *mutabilis* Ulrich. (may be identical with one or other of the Naungkangyi forms).
Pachydictya sp. (possibly identical with a Northern Shan States form),
Ptilodictya sp. (genus represented in the Upper Naungkangyis and Hwe-Mawng beds of the Northern Shan States),
Protocrisina cf. *ulrichi* Bassl. (an Esthonian species),
Diplotrypa sp.

Brachiopoda—
Orthis pustulifera Reed (the commonest Ordovician brachiopod in the Southern Shan States; very much like *O. irravadica* Reed, from the Naungkangyi beds of the Northern Shan States, and also greatly resembling forms from Scandinavia and from the Shensi province of China).

Orthis (*Glossorthis*) *sylvatica* Reed,
,, (*Dalmanella*) *sinchaungensis* Reed,
,, (*Ptychopleurella*) *pinea* Reed,
,, (,,) cf. *lapworthi* Dav.,
Yeosinella consignata Reed,
Vellamo nemoralis Reed,
Ptychoglyptus shanensis Reed,

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[1] *Pal. Ind.*, New Ser., Vol. XXI, Mem. 3 (1936).

Strophomena (*Actinomena*) cf. *subarachnoidea* Reed. (species known in the Girvan area of Scotland; it resembles in many respects *S. corrugatella* Dav. from the Ordovician of Tonkin and may be identical with the shell described as *Stropheodonta* aff. *corrugatella* (Dav.) from the Hwe-Mawng beds of the Northern Shan States.).
Sowerbyella cf. *himalensis* (Salt.) (species found in the Ordovician of Kumaon). *Sowerbyella wilsoni* Reed (comparable with "*Leptœna*" *trabeata* Lindstr., from the Trinucleus beds of Sweden),
Chonetoidea (*Aegiria*) *yeosinensis* Reed (probably identical with *Leptelloidea* aff. *llandeiloensis* (Dav.) from the Upper Naungkangyi of Lilu, Northern Shan States),
Leptelloidea campestris Reed,
Christiania cf. *tenuicincta* (McCoy) (a British form; found also in the Hwe-Mawng beds),
Christiania aff. *youngiana* (Dav.),
Hemipronites (*Estlandia ?*) sp.,
Porambonites cf. *wahli* Heinr. (a species from Esthonia),
Rhynchocamara cf. *bella* (Fenton) (a species from the Plattin Limestone of Missouri).

Cephalopoda—
Piloceras sp. (resembles *P. platyventrum* Grab. and *P. manchuriense* Endo, from the Ordovician of China).

Trilobita—
Illænus yeosinensis Reed,
Sphærocoryphe sp. (genus is found in the Naungkangyi beds, Northern Shan States).

Ostracoda—
Primitia sp. (genus known in the Upper Naungkangyi beds of Lilu).

s.=Sedaw form.
y.=Form from western Yunnan.

Inliers.—From a small inlier near Taungbu, mapped as belonging to the Pindaya formation, some sixteen miles north of Yawng Hwe, and comprising dark purple and orange shales with micaceous slates and tough, reddish brown, variegated mudstones, a few fossils have been obtained, including *Orthis pustulifera* Reed, *O.* (*Wattsella ?*) *pontilis* Reed (resembling *O.* (*Wattsella*) *unguis* (Dav.) of the Shropshire Ordovician), *O.* (*Dalmanella*) *sinchaungensis* Reed, *Chonetoidea* (*Aegiria*) *yeosinensis* (Reed), *Sowerbyella wilsoni* Reed, *Hyolithes clivei* Reed (a Hwe-Mawng form), *Chasmops* sp. and *Encrinurus* sp.

Southeast of the above locality are further small inliers of similar beds, one of which, overlain by Silurian strata, at the southern end of the White Crow Lake northwest of Konlean, has yielded :[1]

Cystidea—
(*s.y.*) *Heliocrinus* cf. *fiscella* Bather,
,, cf. *granatus* Wahl,
(*s.y.*) *Caryocrinus* cf. *turbo* Bather,
(*s.*) ,, *avellana* Bather,
,, cf. *aurora* Bather ? (resembles the form from the Lower and Upper Naungkangyis),
(*s.*) *Ovocystis mansuyi* Reed,
(*s.*) *Protocrinus* cf. *sparsiporus* Bather.

Bryozoa—
(*s.*) *Diplotrypa* cf. *sedavensis* Reed.

Brachiopoda—
Orthis pustulifera Reed,
,, (*Dalmanella*) *sinchaungensis* Reed,
,, (*Glossorthis*) *sylvatica* Reed,
,, (*Plectorthis*) cf. *dichotoma* Hall (originally described from Indiana; may be a young example of *O. chaungzonensis* Reed, a species from the Lower Naungkangyi beds of the Northern Shan States),
Yeosinella consignata Reed,
Leptœna cf. *richmondensis* Foerste (species occurs in the United States Ordovician),
Strophomena cf. *subtenta* Hall (species occurs in the Ordovician of America),
Sowerbyella cf. *cylindrica* (Reed), (species found in the Middle Bala of Scotland (Girvan),
,, cf. *liliifera*, var. *triangularis* Öpik (an Esthonian form),

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[1] *Pal. Ind.*, New Ser., Vol. XXI Mem. 34, (1936).

- *Sowerbyella* cf. *quinquecostata* (McCoy) (species found in both Lower and Upper Naungkangyis),
- *Skenidioides* cf. *œlandicus* (Wim.) (species occurs in the Leptæna Limestone of Sweden),
- *Porambonites* cf *acutiplicata* Reed (species occurs in the Craighead Limestone of Girvan).

Pteropoda—
- *Hyolithes* sp.

s.=Sedaw form.
y.=Form from western Yunnan.

The Taung-gyi range.—A belt of beds mapped as Pindaya fringes, along its eastern edge, part of the alluvial tract which stretches N.–S. through the centre of Yawng Hwe State on the west side of the town of Taung-gyi, its limestones forming the precipitous scarp and much of the foundations of the Taung-gyi range. Among the beds are: black limestones with calcite veins, simulating Permian types; highly-sheared, chocolate-red, calcareous shales with nodules and rare crinoid stems; bedded grey limestones with argillaceous partings; and pale buff or deep orange-red, fossiliferous mudstones. From the last mentioned, near the village of Taungtha-hla, the following forms have been identified by Dr. Cowper Reed :

Cystidea—
- *Echinoencrines* cf. *angulosus* Pander (species found in the Upper Naungkangyi),
- *Heliocrinus* sp.,
- (s.) *Caryocrinus avellana* Bather (a lower Naungkangyi species).

Bryozoa—
- *Pseudohornera* cf. *bifida* (Eichw.) (species found in Esthonia),
- *Chasmatopora* cf. *orientalis* Reed. (comparable with *Ch. fureata* (Eichw.) from Esthonia),
- *Diplotrypa* sp.

Brachiopoda—
- *Orthis pustulifera* Reed,
  - ,, (*Dalmanella*) *sinchaungensis* Reed,
  - ,, (*Eridorthis*) *liberalis* Reed, (considerably resembling *O. thakil*, var. *subdivisa* and var. *trifida* from the Ordovician of Spiti),
  - ,, (*Eridorthis*) *kalavensis* Reed, (resembling forms form the Trenton of Kentucky and the Ordovician of Shropshire),
  - ,, (*Glyptorthis*) *taungtalensis* Reed,
- *Clitambonites* cf. *ascendens* (Pander) (shows the same characteristic ornamentation as *C.* cf. *squamata* Pahl. of the Lower Naungkangyi beds),
- *Leptelloidea* (*Leangella*) cf. *sholeshookensis* Jones (species occurs in the Upper Bala of Wales),
- *Skenidioides* cf. *œlandicus* (Wim.),
- *Rafinesquina* (*Bekkerella*) *gentilis* Reed (may be identical with *O. subcrateroides* Reed, which occurs in the Lower Naungkangyi and Hwe-Mawng beds),
- *Leptæna* cf. *juvenilis* Öpik,
  - ,, *spectata* Reed (allied to an Esthonian form),

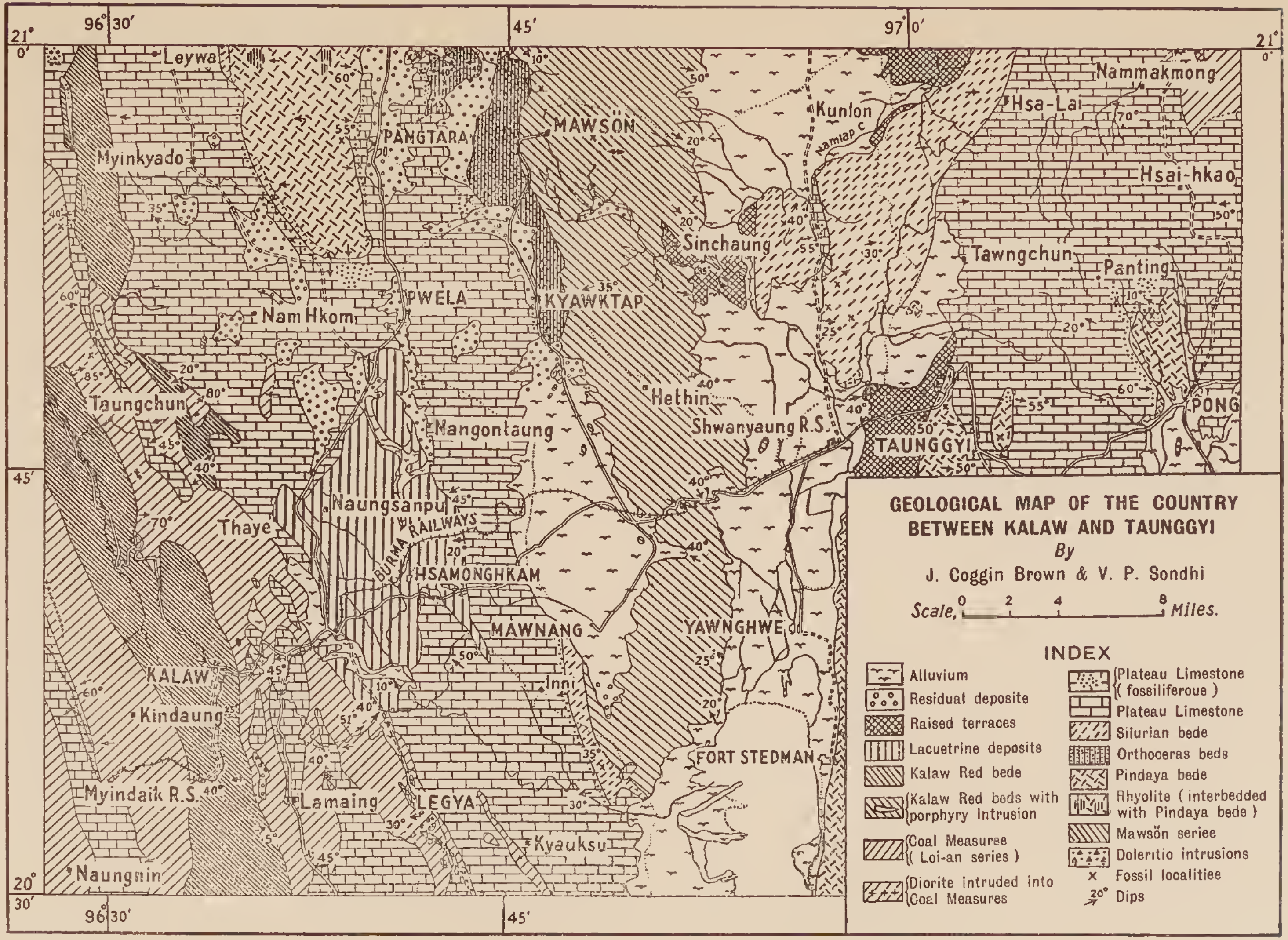
Behind the crag on which Taung-gyi stands is a small inlier consisting mainly of argillaceous limestones weathering to olive, sandy mudstones and yielding a few fossils, among which the following have been identified :

Brachiopoda—
- *Protozyga haydeni* Reed (probably allied to *P. exigua* (Hall) of the Trenton Limestone),
- *Syntrophina* cf. *affinis* (Reed) (a Keisley Limestone species),
- *Leptelloidea* (*Leangella* ?) *lamellata* Reed.

Gastropoda—
- *Loxonema* sp. (suggestive of *L. striatissima* Salt. from the Keisley Limestone).

Trilobita—
- *Phacops* sp.

Exposures further north.—The Pindaya beds continue to the north of their type area into Lawksawk State and beyond, where they are still under


GEOLOGICAL MAP OF THE COUNTRY BETWEEN KALAW AND TAUNGGYI
By
J. Coggin Brown & V. P. Sondhi
Scale, 0 2 4 8 Miles.
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Alluvium
Residual deposits
Raised terraces
Lacustrine deposits
Kalaw Red beds
Kalaw Red beds with porphyry Intrusion
Coal Measures (Loi-an series)
Diorite intruded into Coal Measures
Plateau Limestone (fossiliferous)
Plateau Limestone
Silurian beds
Orthoceras beds
Pindaya beds
Rhyolite (interbedded with Pindaya beds)
Mawsön series
Doleritic intrusions
Fossil localities
20° Dips
21° 0'
96° 30'
45'
97° 0'
20° 30'
Leywa
Myinkyado
PANGTARA
MAWSÖN
Kunlon
Namlap C.
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Kindaung
FORT STEDMAN
Myindaik R.S.
Lamaing
LEGYA
Kyauksu
Naungnin

G. S. I., Calcutta.

examination. Complete accounts of their stratigraphy and faunas are not yet available, but many of the cystideans and brachiopods already tabulated in the preceding lists have been found in these northerly outcrops, together with a number of additional species, among which are the following collected from various localities in the southern portion of Lawksawk :

Cystidea—

Echinosphœra cf. *sinensis* Reed,
Sinocystis loczyi Reed (a Yunnanese form),
,, cf. *yunnanensis* Reed (a Yunnanese species).

Bryozoa—

Pachydictya cf. *elegans* Ulrich (species occurs in the Tronton of Minnesota and in the Kuckers Shale of Esthonia),
Cœloclema (?) *perplexum* Reed (an Upper Naungkangyi form).

Brachiopoda—

Yeosinella consignata Reed,[1]
Orthis pustulifera Reed,
,, (*Hesperorthis*) cf. *laurentina* Billings (a species found in the Ordovician of Quebec),
,, (*Platystrophia*) *prætor* Reed, (perhaps a variety of *O. irravadica* from the Naungkangyi beds),
,, (*Wattsella* ?) *pontilis* Reed,
Vellamo cf. *simplex* ? Öpik (a species found in the Kuckers stage in Esthonia),
Rafinesquina cf. *richardsoni* Reed (pars) (species occurs in the Middle Bala of Girvan),
,, (*Kjœrina*) cf. *felix* Reed (species found in the Drummick beds of Girvan),
Leptelloidea (*Leangella* ?) cf. *derfelensis* Jones (species found in the Lower Bala of Wales),
Leptestia cf. *musculosa* Bekk. (species found in the Kuckers stage of Esthonia),
Skenidioides cf. *billingsi* Schuch. & Cooper (species found in the Black River formation of Quebec).

Trilobita—

Pliomera (*Encrinurella*) *ingsangensis* (Reed) (a typical trilobite of the Upper Naungkangyi and Hwe-Mawng beds of the Northern Shan States),
Pterygometopus dagon Reed (found also in the Upper Naungkangyi and Hwe-Mawng beds),
Harpes cf. *costatus* Ang. (species found in the Leptæna Limestone of Sweden ; may be identical with a form from the Upper Naungkangyi beds),
Prœtus sp. (comparable with *P. ramisulcatus* Nieszk, from the Baltic Borkholm stage),
Agnostus cf. *agnostiformis* (McCoy) (a British species ; the Burmese specimen may be identical with *A. glabratus* Ang. from the Upper Naungkangyi beds),[2]
Eurychilina shanensis Reed,
Remopleurides sp.

Exposures further south.—Further south, in the Taungni area, a fragmentary specimen of *Lichas* sp., possibly identical with an example from the Upper Naungkangyi beds of the Northern Shan States, has also been found.

Exposures east of Taung-gyi.—A few miles east of Taung-gyi, between Hopong and Namkhok, is another poorly-exposed inlier of Pindaya beds, partly concealed beneath the alluvium of the Nam Tamhpak, a valley hemmed in by the limestone hills of the Plateau Limestone.[3]

Further in the same direction is a larger inlying double belt in the State of Möng Pawn. The more westerly strip of this exposure, lying to the west of Möng Pawn town, consists mainly of splintery, greenish-grey shales, sandy shales and purple mudstones, with less frequent sandstones and a solitary band of limestone. From these beds the following few fossils have been collected: *Echinoencrinus* sp., *Orthis pustulifera* Reed, *Clitambonites* cf. *ascendens* (Pand.), *Yeosinella consignata* Reed, and indeterminable bryozoan remains. The larger and more easterly part of this belt includes dark purple mudstones, often nodular and generally bleached, and containing crinoid rings and crushed fragmentary fossils of Upper Naungkangyi age, including *Caryocrinus* sp., *Hyolithes* sp., and the common Upper Naungkangyi trilobite of the Northern Shan States, *Pliomera* (*Encrinurella*) *ingsangensis* Reed. The dip here is high and variable, the band forming part of a closely packed series of folds affecting rocks of both Ordovician and Silurian age. This outcrop has been traced southwards to Loi-lem, to the north of which town some of the purple mudstones have been converted into impure iron ores, which were formerly utilised by the Shans. Loi Lang is built up of red mudstones with fragmentary fossils of Pindaya age, the summit of the mountain being composed of an interbedded limestone; the fossils include cystidean plates, crinoid stems and broken brachiopods. In this locality cauldron valleys and pot-holes in the limestones have been developed to a remarkable extent; between seventy and eighty of these features are shown on the one-inch map within a radius of three miles, both to the northeast and southwest of Loilem, and there are many smaller ones in addition.[1]

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[1] Gen. Rep. *Rec.*, LXIX, 56 (1935).
[2] F.R.C. Reed. *Pal. Ind.*, New Ser., Vol. XXI, Mem. 3, 54, (1936).
[3] J. Coggin Brown and V. P. Sondhi, *Rec.*, LXVII, 136 (1933).

Eastwards of the above belt, no further exposures of the Pindayas are seen till the Salween is reached. On the west bank of this river, small outliers of olive-green shales containing a Pindaya fauna have been faulted into the Chaung Magyi slates.

Beyond the Salween a band of soft mudstones and shales with well-developed limestone bands occurs among Chaung Magyi rocks, twenty miles west of Keng Tung town, and is believed to represent the same formation; the limestone contains argillaceous inclusions arranged in a manner peculiar to Ordovician limestone further west. This is the last occurrence of this early Palæozoic series seen in Burma before the border of Siam is reached.[2]

Correlation.—There is reason to assume that the faunas of the Southern Shan States Ordovician, so far detailed, all belong to horizons at no great distance from one another; in fact, the separate lists given might without serious objection be aggregated into what might be called the Pindaya fauna, and, in the opinion of Dr. Cowper Reed, point to the Upper rather than the Middle division of the Ordovician system. From two horizons of the Ordovician of south Korea, Mr. Kobayashi has recognised several species identical or closely allied to Burmese Ordovician forms, and it is interesting to note that, while the lower of the two Korean horizons (Chikunsan beds), believed to be of upper Llandeilian age, has more in common with the Naungkangyi faunas of the Northern Shan States, the higher horizon (Tsuibon beds), of lower Caradoc age, has somewhat closer affinities with the Pindaya beds of the Southern Shan States.[3] This comparison supports the suggestion that the Pindaya faunas are, in the aggregate, younger than the Naungkangyi fauna. It is to be noted that, with the exception of the cystideans, comparatively few of the same species are common to the Northern and Southern States. There is no clear evidence that the rocks can be divided into Upper and Lower stages in the Southern as they can be in the Northern States, and the Hwe-Mawng beds of the north have not as yet been found in the south.

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[1] Gen. Rep. *Rec.*, LXVI, 100 (1932).

[2] Gen. Rep. *Rec.*, LXIX, 58 (1935).

[3] *Jaurn. Fac. Sci. Imp. Univ. Tokyo*, Sect. II, Vol. III, Pt. 8, 329-519 (1934).

MAWSŎN SERIES.

Another rock series of the Southern Shan States has yielded Ordovician fossils This is the provisional Mawsön series, which may eventually prove to be either the equivalent in part of the Pindaya formation or a facietal variant of the Upper Naungkangyis ; one of its fossil horizons would appear to belong to a lower level than that of any of the Pindaya faunas.

The rocks of the Mawsön series occupy high country bordering the western margin of the Yawng Hwe alluvial tract, from which they rise like cliffs from a sea. Westwards they are succeeded by a younger series known as the "Orthoceras Beds", between which and the Mawsön formation an exact boundary has not been found possible to delineate, though the older beds are distinguishable by their more definite topography of great limestone escarpments and large valleys. The highlands of Mawsön are of the nature of a dome complicated by numerous minor corrugations and possibly faulted along the crest.[1]

The shaly bands of this series are thicker than those in the Orthoceras Beds and have lost the red colour of the latter. The central part of the exposure consists mainly of limestones which give rise to an exceedingly rough country. A common type is a homogeneous, light bluish grey or brown, compact, finely crystalline rock, inclined to be well bedded and very seldom brecciated to any extent.

The limestones contain sandy bands into which they insensibly pass, the rock becoming more and more porcellaneous or earthy and eventually consisting of dirty yellowish brown marls with bluer, more calcareous patches, alternating with fine-grained, calcareous sandstones, silts and mudstones.[2] Middlemiss records as a noticeable feature of the limestones of He-ho, thin interbanded ferruginous layers, about half-an-inch wide, standing out from the weathering surfaces in rugged relief and in some cases consisting of compacted shelly layers of indeterminable mollusca.

The Mawsön beds are described as typical shallow-water deposits. Sections of brachiopods and gastropods are sometimes visible on weathered surfaces of the limestones, as, for instance, west of Bawzaing. When unfossiliferous, the beds are not easily distinguished from the Plateau limestones. Fossils from a sandy siltstone one mile south of Bawzaing have been identified by Cowper Reed as follows :[1]

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[1] J. Coggin Brown. *Rec.*, LXIII, 90 (1930).

[2] J. Coggin Brown and V. P. Sondhi, *Rec.*, LXVII, 222 (1933).

Cystidea—
Cystidean ossicles and plates.

Brachiopoda—
Gonambonites (*Antigonambonites*) *emancipatus* Reed.

Gastropoda—
Lophospira cf. *alternans* Koken (allied to forms from the Lower Ordovician of Manchuria and the Middle Ordovician of south Korea).
,, cf. *elevata* Ulrich & Scof. (comparable with *L. aojii* Endo, from the Lower Ordovician of Manchuria).
Helicotoma cf. *tamurai* Kob. (has a general resemblance to forms from the Lower Ordovician of Manchuria).
,, cf. *planulatoides* Ulrich (species from the Black River formation of America).
Cyrtolites aff. *nodosus* Salt. (a Bala species).

Cephalopoda—
Spyroceras cf. *bilineatum* (Hall) (species from the Black River and Trenton formations of America).

Trilobita—
Ogygites cf. *yunnanensis* Reed (a Yunnanese species).

From a band at the top of Siderite Hill, the southernmost of the two peaks which overlook the enclosed Bawzaing valley on the west, and also from a calcareous sandstone near Sinchaung in the same vicinity, a few brachiopods have been obtained which indicate a slightly different Ordovician horizon :

Gonambonites (*Antigonambonites*) *emancipatus* Reed.
Orthis (*Dinorthis*) cf. *porcata* McCoy.
,, (*Hesperorthis*) cf. *tricenaria* Conrad (species from the Black River and Trenton formations of North America).
Skenidioides cf. *billingsi* Schuch. & Cooper (species from the Black River formation of Quebec).
Rafinesquina cf. *alternata* (Conrad) (species from the Trenton of America),
,, cf. *semiglobosina* (Dav.),
,, cf. *jœrvensis* Öpik (species found in the Kuckers stage of Esthonia),
,, (*Kjaerina*) cf. *prœcursor* Raym. (a Trenton species),
,, (or *Leptœna*) cf. *nubigena* (Salt.) (a Himalayan Ordovician species).
Leptelloidea cf. *leptelloides* (Bekk.) (species found in the Kuckers stage of Esthonia ; a similar shell occurs in the Ordovician of Tonkin).

The Bawzaing beds, as a whole, appear to have no species in common with the typical Naungkangyi series, and only one brachiopod in common with the fauna of the Pindaya beds. The general scarcity of brachiopods and the prevalence of gastropods are the distinguishing features of the fauna found at Bawzaing. The affinities of the fossils, however, indicate, as Dr. Cowper Reed points out, that its age is either Middle or Upper Ordovician, while the gastropods especially suggest a comparison with those described by Grabau and Kobayashi from formations in China which those authors correlate with the Black River group of North America, a formation mainly Middle Ordovician in age. As suggested by Dr. Coggin Brown, it may be that the Bawzain horizon with its particular fauna is only a localised facies of restricted development due to special bionomical conditions of limited extent, but until the fossils which have been collected from the northward extension of the Mawsön series have been described, a final decision is impossible.

In the latitude of Mawsön town, the Mawsön outcrop is seven miles wide. In this northern tract shaly layers are less frequent and the surface is everywhere marked by cauldron valleys and disappearing stream-beds. To the south, the outcrop narrows and one or two zones of intense disturbance make their appearance, with much shearing, crumpling and folding. The lead and silver ores of Bawzaing, described in a later chapter, lie very largely but not entirely within the outcrop of the Mawsön rocks. Old copper workings are seen on the lower slopes of the western flank of the He-ho range to the north of the railway.

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[1] *Pal. Ind.*, New Ser., Vol. XXI Mem. 3, 64-76 (1936).

Northwards, in Lawksawk State, the Mawsön series is represented by a dark grey, highly-jointed, tabular limestone, generally characterised by brownish blotches disposed in most cases irregularly but sometimes in a more or less linear arrangement which, as a result of their greater resistance to denudation, project in small sharp ridges or knobs ; these blotches consist mostly of argillaceous matter.[1] Three outcrops of this blotchy limestone have been recorded, separated from each other by certain mudstones and argillaceous limestones belonging to a younger period ; one of the beds contains lower Silurian graptolites. In one area, it is thought, there may be an almost complete sequence from the Mawsön limestones up to the Plateau Limestone.[2] Northwards the Mawsön blotchy limestones pinch out and the Mawsön-Lawksawk range is built up for the most part of younger siltstones.

The Mawsön series, as a whole, contains few organic remains, but in the railway section, some sixteen miles south of Bawzaing, intensive search has brought to light an additional fossil horizon in the vicinity of the bridge near Namnoi. Originally regarded as Silurian, a conclusion which Coggin Brown and Sondhi found difficult in accepting on stratigraphical grounds, it is now referred to the Ordovician. The fossils are : *Annamitella namnoiensis* Reed, *A. proxima* Reed and *Orthis* (*Paurorthis*) *hehoensis* Reed. *Annamitella* is a unique genus of trilobites founded by the French palæontologist, Mansuy, for a species from the Ordovician of the Annam cordillera. It was at first thought to indicate an Upper Ordovician horizon although, as pointed out by Cowper Reed, the supposed affinity of *Annamitella* with *Bathyurus* and other Lower Ordovician or Upper Cambrian genera, seems opposed to this view. *Orthis hehoensis* which occurs in great numbers in its extremely restricted horizon, appears to be allied to *O.* (*Paurorthis*) *parva* (Pander) of the Lower Ordovician of the Baltic region. The Namnoi occurrence, therefore, is regarded for the time being as belonging to a lower rather than to a higher part of the Ordovician.[3]

THITTEIKKON SPONGE BEDS.

One mile east of the peak (5,098 feet) at Thitteikkon in Lawksawk State occur some beds of unusual interest, comprising a crushed compact, shaly limestone, and an interbedded mudstone. The limestone has yielded a fauna composed entirely of sponges, including *Calathium* (*Calathella*) cf. *anstedi* Billings (a species found in the Quebec group of Newfoundland), *Aulocopium shanense* Reed (a species closely related to *A. aurantium* Osw. of the Ordovician of northern Europe), *A. oviforme* Reed, and a doubtful *Hindia*. From the interbedded mudstone have been obtained : *Echinoencrinus* sp., *Chasmatopora* cf. *orientalis* (Reed), *Orbipora* sp., *Orthis* (*Plectorthis*) *chaungzonensis* Reed, *O.* cf. (*Platystrophia?*)

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[1] Gen. Rep. *Rec.*, LXVIII, 60 (1934).

[2] Gen. Rep. *Rec.*, 72,p 67 (1938).

[3] F. R. Cowper Reed. *Pal. Ind.* New Ser. ,Vol. XXI, Mem. No. 3, p. 125 (1936).

prœtor Reed, and *Rhynchotrema* sp. *Orthis chaungzonensis* is a brachiopod from the Lower Naungkangyi beds of the Northern Shan States and, on the strength of its occurrence, Dr. Cowper Reed concludes that the Thittcikkon beds are probably of about the same age as the Lower Naungkangyis.[1]

ORTHOCERAS BEDS.

Younger than the Mawsön beds, which they succeed to the west, are the Orthoceras Beds. This series, like the Nyaungbaw Limestone, is of extremely restricted distribution. It forms the greater part of the western limb of the broad Mawsön anticline, and has been traced northwards into Lawksawk where its outcrop is interrupted.[2] The band is in places concealed beneath alluvium and disappears southwards under the alluvial deposits of the He-ho-plain. In places the Orthocereas beds have been infolded with bands of yellow, sandy mudstone with badly-preserved fossils recalling those of the Naungkangyi series.

The Orthoceras rocks consist generally of hard, flaggy, brightly-coloured, red pink or purplish, argillaceous limestones and calcareous shales with a highly-developed phacoidal structure which, in the weathered rock, gives rise to a characteristic pattern recalling that of crocodile hide.[3] Lithologically, the beds have much in common with the Nyaungbaw limestones of the outer platform of the Northern Shan States plateau, and probably belong either to the Middle or Upper Ordovician. Usually they contain relics of large crinoid stems and numerous specimens of orthoceracones. The fossils identified by Cowper Reed comprise the following :—

Porifera—
  Receptaculites sp. (very similar to *R. occidentalis* Salt. and *R. arcticus* Eth. from the Arctic Ordovician),
  Archæocyathus (*Archæoscyphia*?) sp. (resembles *A. chihliensis* Grab. from the Lower Ordovician of Chihli province, China).

Hydrozoa—
  Stromatocerium(?) sp.

Gastropoda—
  Lesueurilla sp.
  Raphistoma sp.

Cephalopoda—
  Orthoceras cf. *chinense* Foord (species found in central China),
    ,, cf. *regulare* Schloth. (probably identical with a specimen from Yunnan ; *O. regulare* is a Chinese species),
    ,, cf. *bifoveatum* Nœtl.
    ,, cf. *remotum* Yü (probably identical with *O.* cf. *scabridum* Ang. from Yunnan *O. remotum* is a Chinese species),
  Leurorthoceras(?) sp.,
  Actinoceras (?) sp.,
  Ormoceras (?) sp.,
  Aspidoceras (?) sp.,
  Endoceras sp.,
  Vaginoceras (?) sp.,
  Cameroceras cf. *styliforme* Grab. (species found in Manchuria),
  Cyrtoceras (?) cf. *peitoutzense* Grab. (species found in the Ordovician of north China),
  Oncoceras (?) sp.,

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[1] *Pal. Ind.*, New Ser., Vol. XXI, Mem. 3, 86, 126 (1936).
[2] Gen. Rep. *Rec.*, LXVIII, 60(1934).
[3] J. Coggin Brown and V. P. Sondhi. *Rec.*, LXVII, 219 (1933).

Cyrtactinoceras cf. *boycii* (Whitf.) (species found in Canada),
Centrocyrtoceras (?) sp. (probably identical with *Spyroceras* (?) sp. from Yunnan),
Zitteloceras (?) sp.,
Cryptogomphoceras cf. *turgidum* Troed. (species found in the Cape Calhoun beds of Greenland and the Red River formation of Canada).

Camarocrinus asiaticus, a significant fossil in the Nyaungbaw Limestone further north, appears to be absent. It was at first suggested that the Orthoceras Beds might be the equivalents of the Nyaungbaw Limestone and, like it, represent some of the Ashgillian horizons of the Upper Ordovician in the Baltic provinces, or perhaps even bridge to some extent the Ordovician and Silurian systems as exposed elsewhere. The occurrence of a species of *Endoceras*, however, and the affinities of the rest of the cephalopods, doubtful as most of the determinations are, are thought by some to bring the series nearer to the Trenton Limestone of the Middle Ordovician. Whether there is justification for assuming that all the so-called Orthoceras beds of eastern Asia are on precisely the same horizon, and that therefore, in the absence of better specimens and more specific determinations, the Shan States beds should be regarded as coming from the same general horizons as the well-known Orthoceras-bearing limestones of southern and central China, are matters on which no satisfactory conclusions have yet been drawn. The purplish or reddish limestones of the Burmese Orthoceras beds, and the mode of preservation of the included fossils, are precisely paralleled in the case of the Neichiashan Limestone of Hupeh and other parts of southern China. According to Grabau, the age of the Chinese beds is approximately that of the Orthoceras Limestone of Sweden and of the Vaginatenkalk of the Baltic provinces of Russia.[1] Other authorities suggest that the Chinese Orthoceras limestones range into the Upper Ordovician, and it must be confessed that the stratigraphical position of the Shan States beds fits better with this idea.[2]

YUNNAN.

A considerable assemblage of Ordovician fossils has been collected by Coggin Brown from three localities in western Yunnan.[3]

Near the village of La-meng in the Chinese Shan State of Möng Hkio, west of the Salween, in some hard purple slates probably faulted down into representatives of the Burmese Chaung Magyi rocks, were found a few poorly-preserved fossils, including a species of *Heliocrinus* allied to the species *H. fiscella* Bather, found at Sedaw, a *Harpes* undoubtedly allied to *H. spasski* Eichw. from the Baltic provinces (stage C), and crinoid or cystidean stem joints. The rock lithologically resembles the Hwe-Mawng beds of the Northern Shan States, and may be an argillaceous facies of the Sedaw beds.

The second locality, at which Silurian as well as Ordovician forms were recovered, is a hill-side to the west of the alluvium-filled valley which forms part of the small Chinese district of Shih-tien, a few miles to the south of Young-ch'ang Fu, and west of the Salween. To the east the beds sink beneath the alluvium of the valley, and on the west appear to be overlain by representatives of the Burmese Plateau Limestone. Below the latter, nine horizons have been described by Coggin Brown, but since Silurian graptolites occur in two of these and one of them lies intercalated between two horizons yielding Ordovician fossils, it is evident that the beds have been folded or faulted or both. Omitting the beds containing Silurian fossils, the rocks consist of limestones, marls, black mudstones and decomposed igneous rocks. The section has since been re-examined by Messrs. T. H. Yin and C. H. Lu, who divide the Ordovician part of the sequence into two divisions, a lower which they call the Shihtien Beds, and an upper or Hengshuitang Limestone ; the latter they further subdivide into the *Sinocystis* horizon below, and the *Camarocrinus* horizon above.[1]

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[1] F. R. Cowper Reed. *Pal. Ind.*, New Ser., XXI, Mem. 3, 88 (1936).
[2] *Rec.*, LXVI, 26 (1932) ; F. R. Cowper Reed. *Pal. Ind.*, New Ser., XXI, Mem. 3, 125 (1936).
[3] *Rec.*, XLIII, 327-334 (1913).

Combining the determinations of Dr. Cowper Reed and of Messrs. Yin and Lu, Dr. Coggin Brown gives the following as the fauna of the Shih-tien Beds (*sensu stricto*):[2]

- Graptolitoidea—
  - *Didymograptus nanus* Lapw.,
  - *Dictyonema* sp.,
  - *Desmograptus* sp.,

- Brachiopoda—
  - *Orbiculoidea* sp.
  - *Philhedra sinensis* Reed (related to Baltic forms),
  - *Rafinesquina* sp.,
  - *Orthis* (*Platystrophia* ?) *prœtor* Reed,
  - ,, *irravadica* Reed.
  - *Hemipronites giraldi* (Martelli), var. *yunnanensis* Reed (almost identical with Marbelli's Shen-si-form),
  - *Sowerbyella fasciola* Yin.

- Gastropoda—
  - *Cyrtolitina* sp.,
  - *Paoshenella flexuosa* Yin.

- Cephalopoda—
  - *Endoceras* sp.,
  - *Orthoceras* (*Protocycloceras ?*) *deprati* Reed,
  - *Orthoceras regulare* Schloth.
  - *Trochalites* aff. *macromphalus* Schröder (species found in the Echinosphærite Limestone)
  - *Jovellania* sp. (greatly resembling *J. murrayi* Foord of America).

- Trilobita—
  - *Asaphus* aff. *expansus* Linn. (species found in the Baltic provinces (stage C) ; allied to a form in China and to the Himalayan *A. emodi*),
  - *Illænus* aff. *schmidti* Nieszk. (species found in the Baltic, stage C),
  - *Lichas* (*Metopolichas*) *cclorhin* Ang., cf. var. *coniceps* H. von Leucht. (variety found in the Baltic, stage B),
  - *Ogygites yunnanensis* Reed,
  - *Calymene birmanica* Reed,
  - *Pliomera* (*Encrinurella*) cf. *insangensis* Reed.

  - *Ampyx reedi* Yin,
  - *Phacops* sp.

- Incertae sedis—
  - *Virgulaxonia elegans* Yin.

Dr. Coggin Brown gives good reason for regarding this fauna as belonging to the Upper Skiddavian or Lower Llanvirnian, and the beds may be placed at the top of the Lower Ordovician. The Shih-tien fauna appears to have been found also at Lunschan near the mouth of the Yang-tse Kiang, in Shen-si, and very probably also at Ssu-ch'uan, Hoschan and Shantung.

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[1] *Bull. Geol. Soc. China*, XVI, 41 (1936).

[2] Private communication ; see also *Pal. Ind.*, New. Ser., Vol. VI, Mem. No. 3 (1917), and *Bull. Geol. Soc .China*, XVI, 41 and 281 (1936).

From the *Sinocystis* horizon of this area comes a fauna which is closely related to that of Sedaw in the Northern Shan States, and has many cystids in common with the Ordovician of the Southern Shan States. The abundance of cystideans and the associated cephalopods point to a correspondence with the Echinosphærite Limestone of the Baltic provinces. According to Dr. Coggin Brown, it is to be assigned to the lower part of the Middle Ordovician (Llanvirn-Llandeilo) :

Cystidea—
- *Sinocystis loczyi* Reed,
- ,, *yunnanensis* Reed,
- *Ovocystis mansuyi* Reed (a new genus ; this and the preceding two forms have resemblances to *Aristocystis bohemicus* Barr.),
- *Pyrocystis* (?) *orientalis* Reed (close to *P. pirum* (Barr.) from Bohemia),
- *Eucystis* cf. *raripunctata* Angelin (a Swedish species),
- *Echinosphœra asiatica* Reed (closely allied to "*Echinosphaerites globosus* (Jaekel)" from the Ordovician of Estland),
- ,, *sinensis* Reed (closely resembling *E. aurantium* Gyll.),
- *Sphœronis lobiferus* Reed (resembling *S. globulus* Angelin from Sweden),
- ,, *shihtienensis* Reed (also resembling *S. globulus*),
- *Heliocrinus fiscella* Bather (found at Sedaw and? Lameng),
- ,, *qualus* Bather (found at Sedaw),
- ,, *subovalis* Reed (resembling a Swedish form),
- ,, cf. *balticus* Eichw.,
- *Caryocystis bicompressa* Reed.

Bryozoa—
- *Phylloporina* sp.

Gastropoda—
- *Holopea* sp.,
- *Bellerophon* (*Sinuites*) cf. *rugulosus* Koken (species found in the Baltic, stages B and C).

Cephalopoda—
- *Endoceras wahlenbergi* Foord (found in the Orthoceras Limestone of Sweden and Russia),
- ,, cf. *cancellatum* (Eichw.) (species found in the Orthoceras Limestone),
- ,, aff. *reinhardi* (Boll.) (species found in the Orthoceras Limestone),
- *Orthoceras regulare* Schloth. (found in the Orthoceras Limestone),
- ,, cf. *kinnekullense* Foord (species found in the Orthoceras Limestone),
- *Actinoceras* cf. *bigsbyi* Bronn. (species found in the Black River, Trenton and Galean Limestone, and the Cincinnati group),
- *Trocholites yunnanensis* Reed (resembling *T.* cf. *remelei* Schröd from the Orthoceras Limestone),
- ,, aff. *macromphalus* Schröd. (species found in the Echinosphaerite Limestone),
- *Lituites* sp.

Trilobita—
- *Illænus cæcoides* Reed (allied to Swedish forms),
- ,, aff. *oblongatus* Angelin (species found in the Baltic, stage C).

From the *Camarocrinus* horizon come the following forms as determined by Dr. Cowper Reed, representing probably the Lower and Middle Llandeilo, and the equivalent of the Nyaungbaw Limestone of the Northern Shan States :

- *Camarocrinus asiaticus* Reed,
- *Pyrocystis* (?) *orientalis* Reed,
- *Endoceras* aff. *reinhardi* (Boll.) (species found in the Orthoceras Limestone of Scandinavia),
- *Orthoceras regulare* Schloth. (found in the Orthoceras Limestone),
- ,, cf. *scabridum* Angelin (species found in the Orthoceras Limestone),
- *Cyrtoceras* sp. (noticeably resembling *C. archiaci* de Vern. of the Russian Ordovician, and identical with the Himalayan *C. centrifugum* Salter),
- *Illoenus* aff. *punctulosus* Salter (species found in the Himalaya).

The third locality lies some ten miles east of the Salween river, on a steep hill side north of the Pu-piao plain; here there is a small inlier including a hard, nodular banded limestone, yellow to greenish, highly fossiliferous, hardened mudstones, and more shaly mudstones of a reddish colour. The nodular limestone has yielded crinoid stems and plates of *Caryocrinus* cf. *turbo* (Bather), a Sedaw form, and appears to form the core of a narrow compressed anticline. From the mudstones, which probably belong to higher horizons, the following fauna has been obtained :

- Graptolitoidea—
  - *Didymograptus murchisoni* (Beck) (a British form),
  - ,, ,, , var. *geminus* (Hisinger) (a British variety),
  - ,, *indentus* (Hall) (a British form),
  - *Climacograptus* cf. *scharenbergi* Lapw. (species common in the Glenkiln Shales of Scotland).
- Cystidea—
  - *Echinosphœra* cf. *aurantium* (Gyllenhähl) (species found in the Echinosphærite Limestone),
  - *Echinoencrinus* sp. (allied to *E. senckenbergi* v. Meyer, but differing from the Naungkangyi form).
- Brachiopoda—
  - *Orthis* (*Platystrophia*) *prœtor* Reed,
  - *Streptis* sp. (close to a Wenlock species),
  - *Porambonites* sp.
- Lamellibranchiata—
  - *Ctenodonta* sp. (close to *C. medialis* Ulrich of the Trenton Shales of Minnesota),
  - *Conocardium* sp.
- Gastropoda—
  - *Raphistoma* sp.
  - *Hyolithes* cf. *clivei* Reed (species found in the Hwe-Mawngs),
  - ,, cf. *loczyi* Reed (species found in the Upper Naungkangyis and Hwe-Mawngs).
- Trilobita—
  - *Remopleurides* aff. *latus* Olin. (species found in the Chasmops beds, Sweden),
  - *Ogygites yunnanensis* Reed (very close to *O. birmanicus* Reed of the Hwe-Mawng beds, and recently found in abundance in central and southern China),
  - *Illœnus* cf. *esmarki* Schloth. (species found in the Baltic provinces, stage B),
  - ,, cf. *tauricornis* Kut. (species found in the Baltic Provinces, stage C),
  - *Nileus armadillo* Dalman (found in northern Europe and Ireland),
  - *Bathyurus mansuyi* Reed,
  - *Lichas* (*Metopolichas*) aff. *verrucosus* Eichw. (species found in the Eastern Baltic),
  - *Calymene unicornis* Reed (resembling *C. nivalis* Salt.),
  - *Pliomera martellii* Reed (apparently allied to *P. insangensis* Reed).

The *Didymograptus murchisoni* fauna of Pu-piao appears to be a facies variant of the *Sinocystis* horizon (Cystidean horizon) of Shih-tien, and exhibits affinities with stages B and C of the Ordovician fauna of north Europe.

Graptolite shales have been found by J. W. and C. J. Gregory in the valley of the A-shih-chai, a tributary stream of the Mekong, approximately twenty five miles N.N.E. of Pu-piao. They are regarded as belonging to a higher Ordovician horizon than the latter beds and contain the following fauna :

- *Climacograptus scharenbergi* Lapw.,
- ,, *bicornis* (Hall),
- *Amplexograptus perexcavatus* (Lapw.),
- *Diplograptus* (*Amplexograptus* ?) sp.,
- *Cryptograptus tricornis* (Carr.),

According to Dr. Elles, these forms indicate the zone of *Climacograptus peltifer*, at the junction of the Glenkiln Shales and Hartfell Shales of the Moffat area in Scotland, *i.e.*, the junction of the Lower and Middle Ordovician.[1]

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[1] J. W. and C. J. Gregory. "Geology and Physical Geography of Chinese Tibet", *Phil. Trans.* Ser. B, Vol. 213, pp. 180, 219, 290 (1925). In Australia, *Climacograptus bicornis* has been found in the Llandeilan zone of *Climacograptus peltifer*, while *Cryptograptus tricornis* belongs to the overlying zone of *Climacograptus wilsoni*.

Only the weakest trace of an American element can be detected in the Yunnan Ordovician faunas, and the affinities with the Naungkangyi and Hwe-Mawng beds are not so close as might have been expected. Although several species are closely allied or comparable with the Burmese forms, very few are identical. At the same time, with the Ordovician of the Baltic and Scandinavia the affinities of the Yunnanese Ordovician are just as close as are those of the Shan States beds. The Ordovician of western Yunnan differs in fauna from the Pindaya beds of the Southern Shan States, and a completely different faunistic type seems to occur in eastern Yunnan and Tonkin.[1]

MYITKYINA.

On the Chinese frontier, between Hpimaw and the Fen-shui-ling Pass in north-eastern Myitkyina, Murray Stuart records an outcrop of red, earthy, crinoidal limestones, lithologically very similar to those ascribed to the Ordovician in Yunnan, and associated with yellow shales. South of Chueh-ho they are in contact with brecciated Devonian limestones.

PALÆOGEOGRAPHY.

There are certain difficulties in the way of a reconstruction of events during the Ordovician period in southern Asia, and the problem derives but limited assistance from the Burmese and Himalayan occurrences, owing to their anomalous relationships or their vague position in the Ordovician succession. A review of the facts regarding Ordovician geography, so far as the restricted evidence permits has been presented by Dr. Cowper Reed.[2] There is a more detailed digest in the classic work of Dr. Grabau,[3] and a more recent brief survey by Mr. Kobayashi.[4]

The Ordovician world, during the early and middle epochs of the period, was divisible into three great zoo-geographical provinces: (i) the Atlantic, (ii) the Arctic or Boreal, and (iii) the Pacific.

The fauna of north China belonged to the Boreal province. This northern fauna is represented in the Arctic by limestones with abundant cephalopods, many bryozoa and some corals. It has been found in several parts of Canada (Rocky Mountains, Manitoba, Great Slava Lake and the vicinity of Hudson Bay), in Alaska and in British Columbia; in Europe it has been identified in the Durness Limestone of Scotland, in Spitzbergen and in Bear Island.

The Burmese region belonged definitely to the Atlantic province, as did also southern China, the faunas from both areas pointing clearly to a connection with western Europe, though, as Grabau remarks, the precise path of intercommunication is not yet known; the latter may have been *via* the Russian steppes and Scandinavia as tentatively sketched by that authority. The Burmese fauna possesses a single Bohemian element in the presence of the cystidean, *Aristocystis*, but the other cystideans are north European (Scandinavian and north Russian) types. Whether the Himalayan region formed an individualised sub-province of the Atlantic or a transient portion of the Pacific is a debatable point.

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[1] F. R. Cowper Reed. *Rec.*, LXVI, 204, (1932).
[2] *Rec.*, XL, 17-25, (1910).
[3] "The Stratigraphy of China". I, 42-102.
[4] *Rep. XVIth Internat. Geol. Congr., Washington*, pp. 485-493 (1933).

The major geographical province which occupied south-eastern and eastern Asia during the Cambrian period became subdivided at the commencement of Ordovician times into a northern portion forming part of the Boreal province, and a southern belonging to the Atlantic province. The nature of the barrier between these two portions is a matter still under discussion, but it was situated along the Tsingling mountains and extended eastwards into Korea (Cho-sen).

In the case of Korea, Kobayashi suggests that this line of division, known as the Tsingling-Keijo line and comparable with Logan's line in America and the Caledonian barrier in Europe, was not necessarily a land barrier, but may have been of a similar nature to that which separates the present-day faunas inhabiting the two sides of the Japanese Sea. Here, " the warm Kuroshio current from the south and the cold Oyashiwo current from the north meet off the shore of central Japan, where the cold current is pushed underneath the warm one ".[1] In such a way the " northern " and " southern " Ordovician faunas might have met along a line where deposits would subsequently be found containing members of both assemblages, and the hypothesis receives some measure of support from the fact that such a phenomenon is observable in northern Korea and southern Manchuria where there occurs a repeated alternation of the early Ordovician faunas characterising the two provinces or basins. The intermediate character of this assemblage is seen in its abundant cephalopods and gastropods and in the presence of brachiopod genera such as *Syntrophinella* and *Pomatotrema*.[2] It must be admitted, however, that a deep, submarine trough would be equally efficaceous in hindering or preventing the migration of marine organisms. Chinese stratigraphers, on the other hand, bring forward strong arguments in favour of a land barrier along the Tsingling axis, which towards the late Ordovician gradually emerged and cut off marine communication between north China on the one side and central and southern China on the other.[3]

It is not impossible that the " Tsingling line " may, in some places, have been a land barrier, in others a chain of islands, in yet others a submarine shelf where opposing currents met. We may visualise a barrier of land, probably with a steep rocky coast on one side and a gently sloping shore on the other, crossing the Chinese area from west to east—or perhaps more accurately from W.S.W. to E.N.E.—and prolonged eastwards, beneath the sea which covered the Korean area, in the form of a submarine scarp or shelf, subtended by a trough deep enough to prevent any more than a local and transient mingling of the two faunas, caused mostly by members of the shallow-water assemblage being swept over the edge of the shelf. In some such way the Korean peninsula and the Japanese islands might have been the meeting ground of the " northern " and " southern " faunas. The steep scarp of the barrier, fronting deep water, may have been some major line of faulting.

Whatever may have been the nature of this line or belt of separation, it divided eastern Asia into a northern portion closely related to the Arctic, and a southern containing a fauna with pronounced affinities to European faunas. With this scheme the faunas of the Himalaya and of Burma frankly do not fit. Although the former appears to lie upon what should have been the line of communication connecting the "Atlantic" or European fauna of Burma, Indo-China and southern China with faunas of the same type in the Karakoram, the Pamirs, central Asia, the northern end of the Urals and a large part of Europe, it shows no affinities with the faunas of any of these areas. With the Boreal fauna it is equally unrelated. As already pointed out, it is a highly individualised fauna but with a strong American or "Pacific" element. Cowper Reed finds it difficult to see how the immigration of American types into the Himalayan region can have crossed the strong European life-wave which seems to have flooded eastern Asia from the beginning of the period to the early part of Upper Ordovician times. It is probable, however that the American element reached the Himalayan area by way of the channel across China, for the latter country is not without this element; in Southern Korea, in fact, European and American faunas are described as alternating repeatedly during Ordovician times. Why no appreciable relics of the American element are perceptible in Burma is, however, not easy to understand. It is possible that the faunal differences between Burma and the Himalaya have been exaggerated by the accidents of collecting and, that these differences will diminish as a result of further finds in the two regions or, still more, by the discovery of connecting faunas in intermediate regions. It is safer, however, to regard the matter for the present as an unsolved problem. The copious Ordovician graptolite fauna of Australia, ranging from the Arenigian to the Ashgillian, has not been observed in either Burma or India, though the Llanvirnian and Llandeilian graptolites and other fossils have been found in Pyunnan.

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[1] *Rep. XVIth Internat. Geol. Congr., Washington*, 490 (1933).
[2] T. Kobayashi *Jap. Journ., Geol. & Geogr.*, XI, 163 (1934).
[3] T. K. Huang. *Bull. Geol. Soc. China*, X, 63 (1931) ; A. W. Grabau. *Ibid.* XV, 32 (1936).

In China the Ordovician is widely distributed, and there are places where the uppermost Cambrian is followed by the basal Ordovician with no apparent unconformity, and no changes but those of sedimentation and fauna. Such conditions are also seen in southern Korea where the faunal change from the *Eo-orthis* zone of the Upper Cambrian to the asaphid trilobites of the Lower Ordovician is marked, and where the one fauna is separated from the other only by the unfossiliferous Doten Quartzite which has been taken as the base of the younger system. Frequently, however, there is in southern China a gap of varying magnitude between the Lower Ordovician deposits and those laid down later in the period, indicating a retreat of the sea and formation of land followed by re-submergence due to re-invasion of the ocean. Before the beginning of Silurian deposition there seems, in fact, to have been another more extensive emergence of land stretching right across China from Kueichou (Kwei Chau) to Kiang-su, as witnessed by the marked erosional unconformity between the Orthoceras Limestones and the Lower Silurian shales.[1]

The Orthoceras fauna of central China has close affinities with that of the Scandinavian Orthoceras Limestone, and more especially with that of the Glauconite and Vaginoceras limestones of the Baltic provinces, possessing at the same time more than mere traces of an American element in the presence of *Bathyurus* and the peculiarly American genus *Gonioceras*; incidentally, a very doubtful specimen of the latter has been recorded in the Himalayan fauna. There is, however, nothing in China or Burma to compare really with the latter, though traces of American affinities are not entirely absent also from the Burmese assemblages.

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[1] C. C. Yu. *Bull. Geol. Soc. China*, XII, 41 (1932).

During the later part of the Ordovician period, the three provinces noted above became to a considerable degree confluent, the result being a fauna of cosmopolitan aspect, at least in the northern hemisphere. Of the Upper Ordovician in Asia information is still somewhat scanty. It is thought to have been recognised in the Southern Shan States, and fossils from various parts of China indicate its presence there. In the Himalayan region, there appears to have been no break in the continuity of deposition and no noticeable change in the character of the sediments until the Muth Quartzite period which began in late Silurian times.

The Ordovician, therefore, was marked in Burma by an extension into the Northern and Southern Shan States of the sea covering south China and Indo-China. In the Shan States, this sea was depositing silts upon the denuded floor of Chaung Magyi rocks, Bawdwin tuffs and rhyolites. There appears to be evidence of land, consisting mostly of Chaung Magyi beds and the old crystalline rocks, to the northwest and probably also to the east of the present Northern Shan States Ordovician outcrop, with an intermediate cluster of detached islands or shoals. This land seems to have persisted till the end of the Mesozoic era. The largest of the islands, the present peaks of Loi Ling and Loi Pan, show a remarkable thinning-out of the Palæozoic sediments as these strata approach the inliers. None of the older Palæozoic has been found in the Arakan Yoma, but where the meandering coast-line of the Ordovician sea in Burma lay precisely, it would be premature to speculate in the present state of our knowledge. The geosyncline occupied by this sea stretched northwards through Yunnanese Tibet and may eventually be found to have extended southwards into Karenni and Siam; according to the suggestion of M. J. Fromaget, it may have been joined by another through western Yunnan, stretching past Lai-chau southeastwards along the northeastern foot of the Annamite chain.[1] This sea also is thought to have been studded with islands—*quirlandes insulaires*—for the largest of which the name of "Indosinia" has been proposed. In the words of Dr. Coggin Brown, we visualise amongst these islands, "the Ordovician and Silurian seas, usually shallow but sometimes subject to pelagic invasions, registering by the continually varying character of their deposits, by their advances and retreats, the major pulsations of the greater bodies of oceanic waters to which they were connected."[2]

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[1] *Bull. Soc. geol. France*, 5th Ser., T., IV, 152 (1934).

[2] Private communication.

CHAPTER XVII.

SILURIAN.

Distribution. **Spiti** : Extent ; Pin river sections ; Fauna of Stage 1 ; Fauna of Stage 2 ; Fauna of Stage 3 ; Relationships ; Muth Quartzite. **Kashmir** : Zanskar ; Islamabad area; Gagangair section ; Marhaum ; Shamsh Abari ; Punch. **North-west Frontier and Afghanistan. Kumaon** : Readjusted classification ; "The Dark Coral limestone" ; "The Red Crinoidal limestone" ; The Muth Quartzite. Beyond Kumaon. **Burma** : **Northern Shan States** : Position and subdivision ; The Panghsa-pye series; Lower Namhsim stage ; Manaw beds : Upper Namhsim stage : Faunal relationships ; Zebingyi stage ; Relationships of the Namhsim series; Relationships of the Zebingyi satge ; **Southern Shan States** : Equivalents of the Panghsa-pye series ; Equivalents of the Namhsim series ; Equivalents of the Zebingyi Series. **Yunnan.** Palæogeography.

Distribution.—The Silurian nearly always follows the Ordovician wherever the latter occurs in India and has, therefore, been recognised in the Spiti, Kashmir, Ngari Khorsum and Kumaon sections of the Himalaya, and in the Northern and Southern Shan States of Burma, as well as in the Chinese province of Yunnan, and possibly in Afghanistan. It is not impossible that among Peninsular rocks this system is represented by the higher stages of the Upper Vindhyan, though there is no evidence to prove that such is the case.

SPITI.

Extent.—In the upper Pin valley near Prada, in the Kangra district of the Punjab, the Silurian and Ordovician systems lie in a great syncline upon the Cambrian slates, from which they are separated on both sides of the fold by faults. This synclinal band runs southeastwards and eastwards into the Teti valley in Bashahr ; traced northwestwards from the Pin river, the outcrop of Ordovician and Silurian soon comes to an abrupt end. A few miles to the northeast of this synclinal axis, the two systems again make their appearance on the flank of the anticline into which the Cambrian slates have here been folded. When traced eastwards this band, after curving round a pitching syncline, forms the northern side of the Thanam valley for some distance, and ends northeast of the Hangrang Pass after being interrupted and disturbed by faulting. At the Pass, these beds have been eroded during pre-Permian times to such an extent that, in places, Permian beds rest directly upon the Ordovician red quartzite. Followed northwestwards, this band of Ordovician and Silurian has been recognised in a crushed and faulted condition at Trakse near the Pass known as the Kunzam La,[1] and persists up to the Chandra river, along the left flank of which it continues probably into north Lahaul where its presence has been recorded ; in what proportions the Ordovician and Silurian are here represented is not known.

Pin river sections.—The best sections lie on both sides of the Pin river between Muth and Shian, where the succession is as follows :—

4. White "Muth Quartzite" (probably most of it Devonian), passing gradually down into,
3. Reddish brown quartzite, passing down through calcareous quartzite into hard, grey, siliceous limestones, weathering red and pink (thickness about 80 feet) ;
2. Grey, siliceous and flaggy limestones, weathering red and brown, with red and brown marls, (thickness about 70 feet) ;
1. Grey limestone with well preserved corals in large numbers (thickness about 50 feet).

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[1] The only fossils from this locality are brachiopods of doubtful identification and probably, Devonian age. F. R. Cowper Reed. *Pal. Ind.*, Ser., XV, Vol. VII. Mem. 2, p.4 (1912).

Fauna of stage 1.—The lowest stage, No. 1, has been identified also in the Parahio valley, in the Thanam valley and in the Lipak river section ; it has yielded the following corals :

Propora himalaica Reed (a common and characteristic fossil, comparable to *P. americana* (Edw. & Haime) of the Niagaran formation),
Streptelasma (or *Zaphrentis*) sp.,
Stylaræa kanaurensis Reed,
Favosites spitiensis Reed (much resembling *F. forbesi* Edw. & Haime from the " Silurian " of the New Siberia Islands, and also close to the American species *F. corrugatus* Wellere),
Halysites catenularia Linn., *var. kanaurensis* Reed,
,, *wallichi* Reed.

Fauna of stage 2.—From the next stage, No. 2, in the Muth and Lipak river sections, have been collected :

Brachiopoda—
Orthis (*Dalmanella*) *basalis* Dalman, var. *muthensis* Reed (*O. basalis* is a British form),
,, ,, cf. *edgelliana* (Salter, M. S.) (species found in the British Wenlock),
,, (*Plectorthis*) *spitiensis* Reed (resembling varieties of *O. thakil* Salter),
Stropheodonta compressa (Sowerby) (a British Llandovery form),
Calostylis dravidiana Reed,
Leptœna rhomboidalis Wilckens (a cosmopolitan species in the Ordovician and Silurian, perhaps identical with *L. tenuistriata* Sow.),
Strophonella cf. *euglypha* (Hisinger),
Orthothetes aff. *pecten* (Linne),
Camarotœchia sp. (resembling several Silurian species).

Trilobita—
Calymene ? sp.

Fauna of stage 3.—In the succeeding stage, No. 3, the following assemblage was obtained from Parahio, Muth and Shian :

Actinozoa—
Lindstrœmia sp.,
Favosites cf. *forbesi* Edw. & Haime (species found in Britain and Timan (Russia), in the latter locality accompanied by *Pentamerus oblongus* Sow.),
,, cf. *niagarensis* Hall.

Brachiopoda—
Orthis aff. *rustica* Sow. (species found in Britain),
Orthothetes aff. *pecten* Linne,
Pentamerus oblongus Sow. (a widely distributed species, found among other places in Siberia).

Lamellibranchiata—
Palæoncilo cf. *victoriae* Chapman (species found in the Silurian of Victoria, Australia).

Gastropoda—
Bellerophon sp.,
Euomphalus cf. *triquetrus* Lind.

Cephalopoda—
Orthoceras cf. *annulatum* Sow. (species found in Europe and North America).

Relationships.—The base of the Silurian is drawn at the lower boundary of Stage No. 1 by reason of the corals with Silurian affinities found in that stage ; these corals show a remarkable relationship to American forms, the most significant being that between *Propora himalaica* and *P.* (*Lyellia*) *americana*. Amongst the fossils from the two higher horizons, European affinities on the whole predominate, although " the strong European facies represented in Burma is not.... developed, and the peculiar local characters found in Tonkin are absent."[1] In spite of the Gothlandian affinities of the corals in Stage 1, the presence of such an Ordovician type as *Stylaræa kanaurensis* may be regarded as bridging the change

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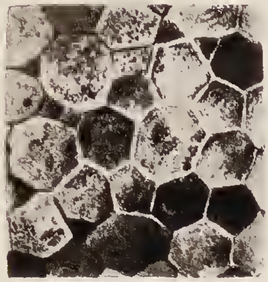
[1] F. R. Cowper Reed. *Pal. Ind.*, Ser., XV, Vol. VII, Mem. 2, p. 168 (1912).



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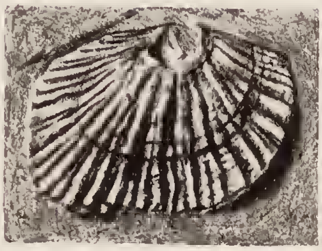

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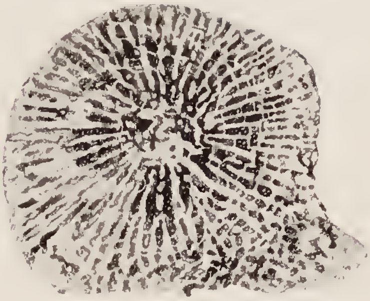

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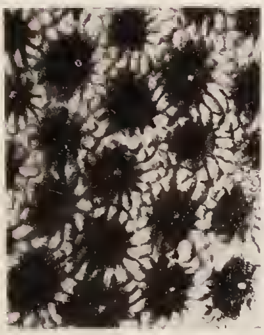

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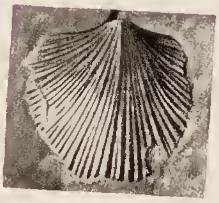

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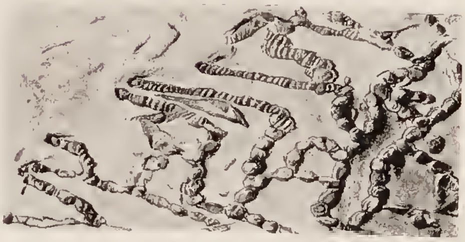

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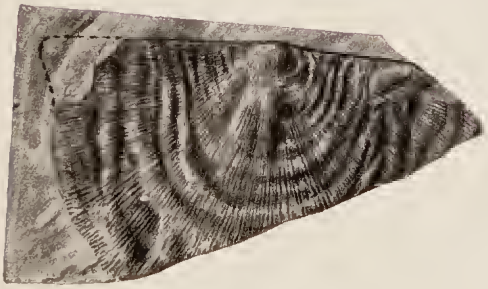

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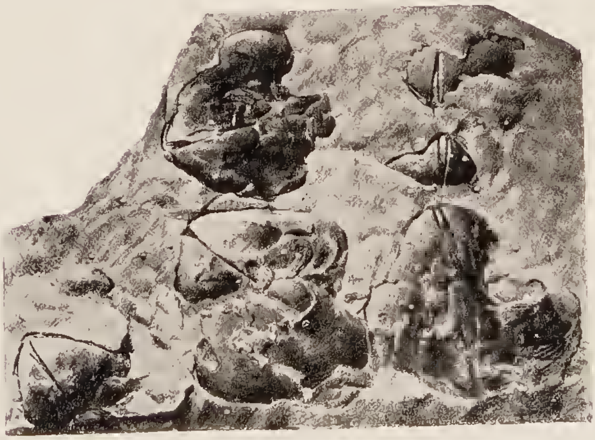

8

SILURIAN FAUNA.

1. *Favosites spitiensis* Reed. 2. *Orthis (Plectorthis) spitiensis* Reed. 3. *Calostylis dravidiana* Reed. 4. *Stylaraea kanaurensis* Reed. 5. *Orthis (Dalmanella) basalis* var. *muthensis* Reed. 6. *Halysites catenularia* var. *kanaurensis* Reed. 7. *Leptaena rhomboidalis* Wilckens. 8. *Pentamerus oblongus* Sow.

G. S. I., Calcutta.

from Ordovician to Silurian. In Stage 2 the fauna has completely changed its character with the change in sediment, and gives indications of being Llandovery in age. Stage 3 must be assigned either to the Llandovery or Wenlock, for *Pentamerus oblongus*, although not occurring above the Llandovery in the British Isles[1].

While the Ordovician of this region and of the Kumaon Himalaya shows practically no European affinities but has close relations with America, the Silurian fauna, although exhibiting distinct American traits in the corals, is on the whole nearer the European. The strong European facies found in the Silurian of the Shan States of Burma is, however, not developed in the Himalaya.[2]

Muth Quartzite.—The topmost bed of the above succession is a hard, white quartzite, frequently containing brown specks of ferruginous matter, and known as the Muth Quartzite. In the type area W.S.W. of the village of Muth, it forms a great wall of rock nearly 500 feet high, dipping at about 50° to the northeast. The Muth Quartzite constitutes a recognisable and conspicuous horizon, ranging in this region from 350 to 800 feet in thickness. Since it passes downwards very gradually into the calcareous quartzites and siliceous limestones with *Pentamerus oblongus*, and upwards without a break into a series of hard, siliceous limestones with Middle Devonian fossils, it appears to represent Middle and Upper Silurian and Lower Devonian, constituting perhaps a conformable bridge between the two systems and evidently covering a relatively long period of geological time.

KASHMIR.

Zanskar.—From the Bara Lacha Pass at the head of the Chandra valley a belt of the so-called " Panjal system " has been mapped extending into western Kashmir and uniting with another parallel band on the other side of the Zanskar *massif* in an extensive exposure around Srinagar. To what extent, if any, the Silurian is represented in these Panjals is not yet known.

Islamabad area.—Fortunately, a band of unmistakable Silurian containing a fairly representative fauna and accompanied by the Muth Quartzite was discovered by Middlemiss in western Kashmir thirty or forty miles southeast of Srinagar. This is no doubt a continuation, interrupted or otherwise, of the Silurian belt of Spiti. Here, in a N.W.-S.E. anticline pitching towards the northwest across the Lidar river, and in a contiguous syncline rising towards the southeast, older slates of Ordovician or Cambrian age are succeeded first by 100 feet of blue-grey, rusty-weathering, sandy shales, patchily calcareous, and fossiliferous ;[3] these pass up into typical Muth quartzite which in places is as much as 3,000 feet thick.[4] The quartzite is succeeded in turn by the Lower Carboniferous limestone or the Panjal Volcanics.

The organic remains in the sandy shales consist for the most part of internal casts or external impressions and are poorly preserved. The following are among those identified : [5]

Actinozoa—
- *Lindstrœmia* cf. *bina* (Lonsd.) (species found in Great Britain),
- *Alveolites repens* (Fougt). ?

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[1] It is found in the Clinton of America, but this formation is placed by many authorities in the Llandovery (Valentian).

[2] F. R. Cowper Reed. *Rec.*, XLII, 71 (1912).

[3] The fossiliferous Silurian which, according to Middlemiss, original map of Kashmir (Rec., XL, PL. 39 (1910)), fringes and parallels the outcrop of the Muth Quartzito throughout, has not been shown separately in the accompanying map, wherein the two formations have been shown together as one band bearing the symbol of the Quartzite in the region east of Islamabad.

[4] C. S. Middlemiss. *Rec.*, XL, 216 (1910).

[5] Gen. Rep. *Rec.*, XLI, 65 (1911) ; F. R. Cowper Reed.—18 *Rec.*, XLII, 16 (1912).

Brachiopoda—
Orthis (*Dalmanella*) *basalis* Dalman, var. (by far the most abundant species),
,, ,, *elegantula* Dalm. (a cosmopolitan species),
,, ,, aff. *bouchardi* Dav. (abundant ; species found in Great Britain),
,, ,, cf. *crassa* Lindstr.,
,, (*Plectorthis*) cf. *spitiensis* Reed,
,, *rustica* Sow. (European species),
,, *sowerbyana* Dav. (British Llandovery form),
Pholidops implicata Dav. (found in the British Llandovery),
Leptæna rhomboidalis Wilck. (cosmopolitan species),
Triplecia insularis Eichw. (this species is not found above the Upper Llandovery in England, and the genus does not occur above the Clinton in America),
Leptelloidea aff. *papillosa* (Reed) (found in the St. Martin's beds of Wales),
Plectambonites transversalis Dalm,
Strophonella cf. *euglypha* (His.) ? (species found in Great Britain),
Strophomena antiquata (Sow.) ? (species found in Great Britain),
Stropheodonta cf. *applanata* (Salt.) (species found in Great Britain),
Camarotœchia cf. *nucula* (Sow.) (species found in Great Britain),
Wilsonia cf. *wilsoni* (Sow.) ? (species found in Great Britain),
Rhynchospira aff. *bouchardi* (Dav.),
Atrypa marginalis Dalm., var. (forma typica found in Great Britain),
Meristella or *Merista* sp.

Cephalopoda—
Orthoceras cf. *tenuiannulatum* McCoy. (species found in the Upper Llandovery and Ludlow of Great Britain),
Cyrtoceras sp.

Trilobita—
Calymene cf. *blumenbachi* (Brong.) (species found in Great Britain),
Acidaspis kashmirica Reed (greatly resembling *A. deflexa* Lake, of Great Britain),
Illænus aff. *macallumi* Salt. (species found in Great Britain),
Encrinurus cf. *punctatus* (species found in Great Britian),
Primitia sp.,
Beyrichia sp.

The above fauna, collected from three localities all of which appear to belong to the same horizon, may be assigned with considerable confidence to some part of the Llandovery. From a fourth locality, "under Margan Pass",[1] the two forms, *Orthis basalis* Dalm., var. and *Conchidium* cf. *knighti* (Sow.) have been obtained ; if the latter is rightly compared, this horizon would seem to be somewhat higher and belong to the Aymestry Limestone. Although the American element is not wanting in these assemblages, the predominating affinities are undoubtedly with north Europe.

The Muth Quartzite is exposed continuously, except where covered for short distances by alluvium, in this anticline pitching towards the northwest and lying between two synclines rising towards the southeast. It follows in normal sequence above the beds with the Upper Silurian fossils and is unusually thick. Like its equivalent in Spiti and Kumaon, it is a massive unfossiliferous quartzite, granular in texture and typically white in colour with spots and patches of ferruginous matter ; its lowermost beds become thinner-bedded siliceous shales where it passes down into the fossil-bearing Upper Silurian, with which it is here invariably in contact. Its upper boundary is in contact with the Syringothyris Limestone (Lower Carboniferous) or, where this is missing, with the Agglomeratic Slate or the Panjal lava flows, both members of the Panjal Volcanic series, the lower horizons of which have been assigned provisionally to the Upper Carboniferous. Unlike the older Palæozoic rocks of this region, the Muth Quartzite produces a

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[1] Not the Lutherwan locality, though close to it.

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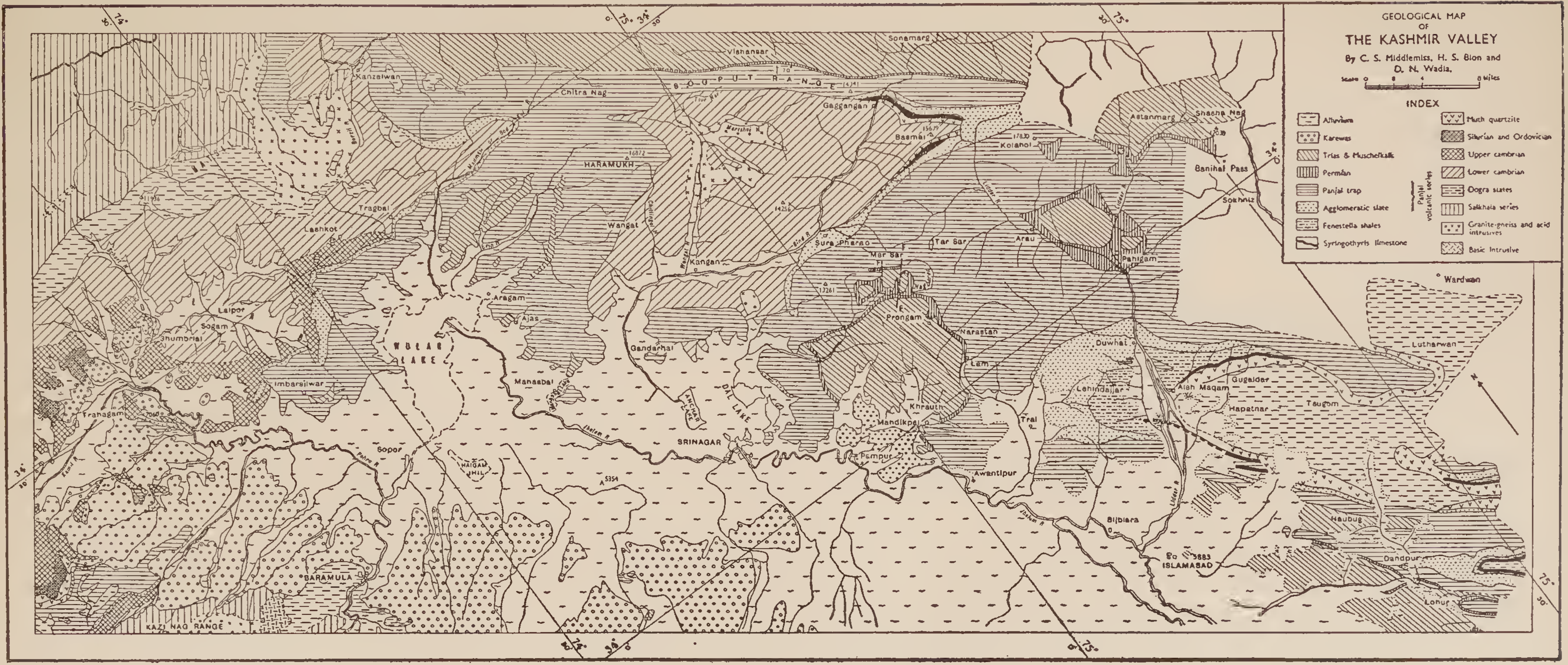
GEOLOGICAL MAP
OF
THE KASHMIR VALLEY
By C. S. Middlemiss, H. S. Bion and
D. N. Wadia.
Scale 0 2 4 8 Miles
INDEX
Alluvium
Karewas
Trias & Muschelkalk
Permian
Panjal trap
Agglomeratic slate
Panjal volcanic series
Fenestella shales
Syringothyris limestone
Muth quartzite
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Basic Intrusive
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5883
Haubug
Dandpur
Lonur
BARAMULA
KAZI NAG RANGE
Liddar R.
Sind R.
N
34°
74° 30'
75°
75° 30'

G, S. I., Calcutta.

topography of very prominent cliffs and precipices, especially where the dip is only moderately steep.

Gangangair section.—Reference has already been made to the Gangangair section in the lower reaches of the Sind valley, some twenty-five to thirty miles northeast of Srinagar, a continuation probably of the exposures just described. The older graywacke and slate system of Ordovician and possibly Cambrian age is present, and thin-bedded Silurian slates are described as being succeeded in the characteristic way by typical Muth Quartzite; the latter, dipping at about 60° to the northeast, is found on both sides of the Sind valley but is only a few hundred feet thick. The *Orthis* fauna of the rocks further southeast has not been discovered here, the beds appearing to be devoid of fossils.

Marhaum.—Whether any part of the Silurian sequence follows the fossiliferous Ordovician of the Marhaum syncline, north of Handwara (Hundawor) is not yet known.

Shamsh Abari—In the Shamsh Abari syncline to the southwest of the Marhaum outcrop is a larger exposure of variegated slates and sandy and calcareous beds with numerous obliterated fossils. These beds, which overlie the blue clay of the Upper Cambrian, may belong partly to the Ordovician, under which heading they have already been described, but since they appear to pass up without any break into the Muth Quartzite, it is very probable that they include at the same time Silurian horizons.

The Muth Quartzite of this exposure has been traced westwards round the rising syncline in a hairpin loop from one limb to the other. Along part of its lower boundary, this ribbon-like band of hard, snow-white quartzite, here between 1,000 and 2,000 feet thick, follows the older Silurian-Ordovician sequence in an apparently normal manner; along the rest of this boundary it overlies the Upper Cambrian with a concealed unconformity, the only sign of which is the presence on the western slope of Shamsh Abari of a prominent band of purple conglomerate and sandstone.[1] This quartzite, readily identifiable with that in the Lidar and Spiti valleys, is characteristically well bedded and pure white in colour—a silicified sandstone with no partings except occasional thin intercalations of buff-coloured limestone. It is best developed on the northern slope of Palaphati (12,549 feet), extending thence to Pohdalau (10,108 feet), but disappearing suddenly thereafter under the Pleistocene Karewah deposits.

In this part of Kashmir, the Syringothyris Limestone has not been found and no representative of the Lower Carboniferous appears to be present, the Muth Quartzite dipping under the Panjal Trap which, especially at the western end of the syncline, rises above the quartzite in formidable precipices. Eastwards, the narrowing and disappearance of the Muth Quartzite outcrop in the southern limb of the fold is ascribed to overlap by the Panjal Trap, thin lenticular streaks of Agglomeratic Slate intervening here and there.

A small inlier of Muth Quartzite and Upper Cambrian within the Karewah deposits is seen a few miles to the northeast, but elsewhere it and the succeeding horizons of the Palæozoic are absent in this part of Kashmir. As already explained, the age of the Muth Quartzite is probably partly Lower Devonian, but there is good reason to believe that it includes also the higher portions of the Silurian and beds representing the gap which separates these two systems in other parts of the world.

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[1] D. N. Wadia. *Rec.*, LXVIII, 143 (1934).

Punch.—In the state of Punch, a thick series of fossiliferous graywackes and sandy, micaceous slates, found by Wadia at the southeastern extremity of the Reji syncline, about twelve miles to the northeast of the town of Punch, may be assigned provisionally to the Silurian system. These beds, which are obviously some undenuded relics of a thinly-developed formation of Palæozoic age and are accompanied by what appears to be a representative of the Muth Quartzite, occur in a short N.W.–S.E. lenticular strip between the Dogra Slates on the southwest and the basal beds of the Tanawals (Devonian) on the northeast. They are folded in among the corrugations of the Dogras, and for this reason their linear extent as well as their thickness, is obscured by imbrication.[1] In these beds have been found moderately well preserved casts of some slender species of gastropod about one inch long, and doubtful casts and impressions of *Tentaculites* or *Conularia* and of graptolites. By such obscure relics, although insufficiently preserved for specific determination, are the beds distinguished from the barren slates of the Dogra formation among which they are folded.

The fossiliferous beds are succeeded stratigraphically by a zone of massive, white or grey quartzites, quartz-schists and phyllites, with some slates which are sparsely conglomeratic. These thoroughly altered and schistose arenaceous beds differ entirely from the coarse-grained, current-bedded and banded Tanawal quartzite, and resemble lithologically the Muth Quartzite, of which they are probably an attenuated representative in the southwestern flank of the Pir Panjal. No traces of fossils have been detected in these rocks, which are pyritous and slightly calcareous.

The Muth Quartzite has been recognised in the syntactical angle between the Himalaya and the Hazara mountains, where it is some 2,000 feet thick.[2]

NORTH-WEST FRONTIER AND AFGHANISTAN.

The indurated slates and quartzites, referred to the older Palæozoic and forming the main axis of the Safed Koh, continue into the Surghar hills of Afghanistan and include patches of a white quartzite not unlike the Muth Quartzite. It is possible, therefore, that the succession may contain representatives of the Silurian as well as of the Ordovician.[3] The same quartzite and slates, the latter sometimes quite red, were observed by Sir Henry Hayden in Dir and Chitral below Ashreth.[4] Hayden expresses the opinion that there is no reasonable doubt that the Palæozoic of Chitral is the continuation of that of the mountains on either side of Bamian in Afghanistan, through Kafiristan. This belt bends eastwards into Hunza and thence probably southeastwards into the mountains of Baltistan, passing perhaps onwards into the neighbourhood of Leh and Chang Chenmo; it would thus lie outside and to the northeast of the main Himalayan basin of Kashmir, Spiti, Garhwal and Kumaon.

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[1] *Mem.*, LI, 232-233 (1928).

[2] D. N. Wadia. *Rec.*, LXV, 203 (1931).

[3] H. H. Hayden. *Mem.*, XXVIII, 106 (1898).

[4] *Rec.*, XLV, 277 (1915).

The Kalu series of northern Afghanistan is said to recall the Haimanta system of the Himalaya. It is followed by a thick band of hæmatite and two limestones associated with each other, the one with Upper Devonian, the other with Lower Carboniferous fossils ; whether the Silurian is present in this area or not, it is not yet possible to say.[1]

The greater part of the Hindu Kush and the Koh-i-Baba is formed of Palæozoic beds.

KUMAON.

Readjusted classification.—The lower Palæozoic succession in Kumaon has been outlined in chapter XVI, where it has been suggested (i) that the " Dark Coral limestone "—Griesbach's " Devonian limestone " (included on his map apparently with the " Lower Carboniferous ") or group (6)—may be astride the Ordovician and Silurian and correspond to some or all of the three uppermost of the local Ordovician stages as well as the lowest Silurian stage of the Spiti area ; (ii) that Griesbach's group (7), the Red Crinoidal limestone, of supposed Lower Carboniferous age, represents stages 2 and 3 of the Spiti Silurian ; and (iii) that the White Quartzite is in most cases—as Griesbach himself concluded—the Muth Quartzite of Spiti which is presumed to bridge the Silurian and Devonian and to include horizons belonging to both these systems. Griesbach's group (5), consisting of bedded pink quartzites with intercalations of greyish green shale and assigned by him to the " Upper Silurian " (*i.e.* the Silurian proper, translated into modern nomenclature), has already been dealt with under the heading of Ordovician, since it contains Ordovician and not Silurian fossils. It may be the equivalent of the Spiti stage (*d*), which it so much resembles and which occurs near the base of the Spiti Ordovician, but the possibility of its belonging to the place allotted to it by Griesbach—*i.e.*, above instead of below the Ordovician limestone, group (4)—must not be overlooked and must await further fieldwork in an inaccessible region. The sequence we have now to consider is that appearing on Griesbach's map as " Lower Carboniferous " and in his text as " ? Devonian and Lower Carboniferous ", comprising his groups (6), (7) and (8). It will be seen to accompany the zig-zagging belt of Ordovician (" Silurian ") from the Shanki stream near Niti in north Garhwal to the frontier of Nepal, into which unsurveyed country it obviously continues with the other Palæozoic outcrops. Rarely it occurs as inlying tracts in the Carboniferous (Griesbach's " Upper Carboniferous "), unaccompanied by the Ordovician.

"The Dark Coral limestone".—The Dark Coral limestone,—" group (6) " —which we are tentatively assuming may contain Silurian horizons at least in its upper portions, is described as passing down with alternations into group (5) ; if this is a correct statement, Griesbach's order of superposition must be accepted. The prevailing rock of this " group (6) " stage is a very dark grey or black limestone in even beds, sometimes flaggy but generally concretionary. The upper part of the stage is characterised by thin partings of calcareous shale, and by the appearance of red and brown, thin-bedded, earthy, crinoid limestone. White veins of calc-spar traverse the beds in all directions and fractured surfaces show numerous sections of fossils, most of them corals and brachiopods, with fragments of crinoids.

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[1] H. H. Hayden. *Mem.*, XXXIX, 23 (1911).

The thickness of the group in the Niti area is 650-700 feet but is said to be much greater in the Milam and Dharma valleys. The Chango peaks (20,216 feet) are formed partly of the limestone which, though unfossiliferous, is developed in great force in the eastern corner of Garhwal (Bhot Mahals).

"The Red Crinoidal limestone."—The "Red Crinoidal limestone", Griesbach's group (7), is described as showing no sharp boundary with the previous group, and as composed of dark grey or brownish red, earthy, crinoid limestones. The beds are generally from 6 to 12 inches thick but are occasionally more massive, and contain siliceous concretions. The thickness of the stage in Niti is 350-500 feet but becomes much greater eastwards owing to intercalations of a light bluish grey, earthy limestone in its lower horizons.[1] The fossils in this stage are very poorly preserved and "casts of brachiopods, *Orthoceras* and crinoid remains may be said to be the sum total of what has been found in these earthly limestones." This remark of Griesbach is significant as affording an explanation of the almost complete absence of Silurian fossils in the collections made by himself and others in the Kumaon area. Nevertheless, even allowing for poor preservation and difficulty of extraction, it seems strange that only one specimen of Silurian character should have been obtained from a fossiliferous belt eighty-five miles in length, which in all probability contains representatives of the fossil-containing beds occurring in Spiti between the Ordovician and the Muth Quartzite. The one specimen, *Encrinurus* aff. *punctatus* Brün., was obtained at the western end of the Lankpya Lek pass into Tibet in either the Red Crinoidal limestone or the Dark Coral limestone.[2] More than one variety of this form is found in both the Ordovician and Silurian of the British Isles. Provisionally we may correlate Griesbach's "Red Crinoidal limestone" with stages 2 and 3 of the Spiti succession.

The Muth Quartzite.—The "White Quartzite", or group (8), is described as a hard, generally fine-grained, thick-bedded quartzite, pure white in colour and often resembling a white marble in texture. At its base are rare intercalations of the underlying Red Crinoidal limestone, while its uppermost portions often consist of a fine grit or quartz sandstone with a few intervening shaly beds. Its upper boundary in places is rugged and denuded and shows distinct erosion, which witnesses to the stratigraphical gap between it and the overlying *Productus*-containing Permian; in fact the White Quartzite is sometimes completely wanting. There seems little doubt that the greater part of the quartzite assigned to this position by Griesbach is the Muth Quartzite of Spiti, though it differs therefrom by containing rare fossils; these, consisting of brachiopods, *Orthoceras* and corals, are scarce and generally seen only on weathered surfaces. The thickness of this stage in the Niti area is about 350 feet but further to the south-east swells to 600 or 800 feet; near Rimkin Paiar it is about 700 feet. In the Dhauli Ganga valley, it is said to be at least 2,000 feet in thickness, but since it is said to contain here casts of *Productus*, it is possible that one of the younger Carboniferous or Permian limestones has been mistaken for or included in the Muth Quartzite.[3] The precipitous cone (19,518 feet) seen on one side of the Marchauk

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[1] C. L. Griesbach. *Mem.*, XXIII, 61 (1891).

[2] F. R. Cowper Reed. *Pal. Ind.*, Ser. XI, Vol. VII, Mem. 2, p. 142 (1912).

[3] The Muth Quartzite both in Kumaon and Spiti, was regarded by C. L. Griesbach as of Upper Carboniferous age.

Pass is made up of the White Quartzite, and the same rock forms the towering precipices on each side of the Chorhoti Pass.

Beyond Kumaon.—Southeast of the Kumaon exposures stretches another extensive tract of unmapped territory through the State of Nepal. In the Lhassa traverse no Silurian rocks were definitely identified, so that the nearest known exposures of this system in this direction are those of Burma.

BURMA.

NORTHERN SHAN STATES.

Position and subdivision.—The Silurian is well developed in the Northern Shan States of Burma, where the greater part of it is seen as a belt, accompanied by interrupted patches of Ordovician, separating the outcrop of the Chaung Magyi formation from that of the Plateau Limestone. It has been investigated and described by La Touche who discovered the first graptolites of southern Asia in the lower stages thereof. The Silurian rocks of this region have been divided into the following groups :—

Zebingyi series (local).		Ludlow.	Upper Silurian.
Namhsim series	Upper, or Konghsa Marls. Lower, or Namhsim Sandstone.	Wenlock Limestone. Most of the Wenlock Shales.	Middle Silurian.
Panghsa-pye series.	Upper or Graptolite stage. Lower or Trilobite stage.	Llandovery to the base of the Wenlock Shales.	Lower to Middle Silurian.

The Panghsa-pye series.—Of the lowest of the three series a comparatively clear section is to be seen at the base of a scarp of higher Silurian rocks near the village of Panghsa-pye, about eight miles northwest of the town of Hsipaw, where the whole conformable sequence dips to the southeast at about 30°.[1] Two stages have so far been recognised in the Panghsa-pye series—a trilobite stage at the base and a graptolite stage consisting of three zones, (1), (2) and (3), above. This is the only locality in which the Trilobite stage has been observed; it comprises a yellowish sandy shale in which have been found[2] :—

Actinozoa—
Palæocyclus haimei Reed (closely related to a British form).

Brachiopoda—
Pholidops implicata (Sow.),
Philhedra sp.,
Orthis (*Dalmanella*) *basalis* Dalm,
,, ,, ,, *elegantula* Dalm. (here very rare),
,, ,, *mansuyi* Reed (closely related to *O. edgelliana*),
,, aff. *bouchardi* Dav.,
,, aff. *canaliculata* Lindstr. (species found in Great Britain),
Scenidium(?) *medlicotti* Reed (resembles *S. lewisi* (Dav.), especially the variety *woodlandense* Dav., found in the British Middle Llandovery,
Triplecia sp.,
Stropheodonta mcmahoni Reed,
,, *feddeni* Reed (related to a British form),

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[1] T. H. D. La Touche. *Mem.*, XXXIX, Pt. 2, 126 (1913).
[2] F. R. Cowper Reed. *Pal. Ind.*, New Ser., Vol. VI, Mem. 1, 93 (1915).

Schuchertella pecten (Linne) (a widely-spread form),
,, *planissima* Reed (allied to '*Strophomena*' *applonata* Salt of the Wenlock Shales.).

Gastropoda—
Coltonema blanfordi Reed (resembling Gothland forms).

Trilobita—
Acidapis shanensis Reed (comparatively abundant but no specimen complete),
Phacops (*Dalmunites*) *hastingsi* Reed (close to a Scandinavian as well as to a British form),
Bollia alexandri Reed,
Klœdenella(?) *birmantea* Reed (related to an American Silurian form),
Primitiella(?) *orientalis* Reed (allied to a Welsh Bala form),
Turrilepas sp.

The facies of this fauna and its affinities are Llandovery and, since the band occurs below a graptolite zone of Lower Llandovery age, it must correspond more or less to the base of this series.

The lowest zone of the graptolite band at Panghsa-pye, consists of about 50 feet of fine, white shales, lying upon the trilobite stage. It has also been identified near Hsipaw and at two localities near Ping-hsai on the eastern flanks of the Loi Pan range, upon the top of the Hwe-Mawng beds; at one locality the shales are highly carbonaceous and sandy with lenticular bands of coaly matter. This horizon is characterised by the following graptolites :—

Diplograptus (*Orthograptus*) *vesiculosus* Nich. (a common species at Ping-hsai),
,, (*Mesograptus*) *modestus* Lapw. (especially common at Ping-hsai)
,, (*Glyptograptus*) cf. *persculptus* Salt. (found only in the black shales of Ping-hsai; species found in the British Lower Llandovery),
Climacograptus medias Törnq. (common at Panghsa-Pye),
,, *rectongularis* McCoy,
Monograptus tenuis Portl. (common at Ping-hsai),
,, *cyphas* Lapw., var. (sparingly represented),
,, *concinnus* Lapw. (abundant at Ping-hsai; in Great Britain this form ranges from the zone of *M. gregarius* to that of *M. sedgwicki*).

The age indicated by these beds is that of the zone of *Orthograptus vesiculosus* or *Monograplus cyphus* of the Lower Llandovery of Europe; the Ping-hsai graptolites belong to the upper part of this zone.

The second zone has been found at the village of Ngai-tao in the Nam Tu valley some eighteen miles N.N.E. of Panghsa-pye, and has yielded a fauna belonging to the zone of *Monograptus gregarius*, higher up in the European Llandovery, including :—

Diplograptus (*Mesograptus*) *modestus* Lapw.,
Climacograptus törnquisti E. & W. (common in the Lower Birkhill Shales of Great Britain and Ireland, especially in the one of *Monograptus gregarius*),
Monograptus gregarius, Lapw. (abundant),
Monograptus cyphus, var. *minor* Lapw. (apparently the same as the Ping-hsai form),
Rastrites peregrinus (abundant).

The third zone is to be seen near the village of Kanlun, eleven miles southeast of the town of Möng Yai in the eastern hill ranges. The two graptolites found therein *Monograptus priodon* Barr. and *Cyrtograptus* sp.—point to a still higher horizon in the Silurian, probably to the base of the Wenlock Shales.

The narrow Graptolite band has been mapped to the east of Bawdwin; separating the Naungkangyis on the west from the Namhsim Sandstone on the east. It is best exposed in the valleys of the Nam Tu, Pangyum and Nam La, traced northwards it dies out beneath the overlapping Namhsim Sandstones. It is a thin band of carbonaceous sandy shale with large number of graptolites, most of which are too ill-preserved for determination but among which *Monograptus* has been recognised.[1]

Graptolite beds have been noted at the top of the purple Hwe-Mawng beds close to the small village of Namhsim about eight miles east of Man-se-le, at Pang-sam two miles north of Ping-hsai, and in a locality about two-and-a half miles E.N.E. of the village of Pang-me which is some twelve miles E.S.E. of Lashio; in the last-mentioned spot, the graptolites, including a species of *Climacograptus*, occur not only at the top of the purple Hwe-Mawng beds but also in some white shales interbedded with them.

Lower Namhsim stage.—The Lower Namhsim stage is a sandy shore deposit, sometimes conglomeratic at its base. It is not found in the hill ranges to the east; this may be the result of overlap by the younger Plateau Limestone, but is more probably due to the non-deposition of such coarse sediments so far from the coast—a hypothesis which receives support from the more frequent occurrence in these eastern tracts of the finer marly sediments of the Upper Namhsims.

The basal beds of the Lower Namhsim stage are composed of coarse conglomerates containing boulders of the Chaung Magyi quartzite or, where the conglomerates are absent, of coarse sandstone strongly felspathic for some distance up from their base and generally of purplish or bluish grey colour. This sandstone gradually becomes less felspathic and passes up into the finer, brown variety, with very fine, hard, white, quartzose layers. In one or two inliers of the Naungkangyi series, the Lower Namhsims are seen lying upon the purple zone at the top of the former. Where the Graptolite band is also present, the basal Namhsim sandstones are fine-grained and apparently conformable. The upper boundary of the stage is easily discernible on account of its topographical contrast with the Plateau Limestone which usually overlies it and beneath which the sandstones usually give rise to well-marked and precipitous scarps. In the Nam Tu valley, the Lower Namhsims attain a thickness of at least 2,000 feet. The evidence points clearly to the close proximity of a coast line, and to the deposition of the beds in a sea shallowing rapidly to the northwest in the direction of the old Chaung Magyi land-mass. The character of the strata is not promising from a fossil-collecting point of view, but the softer finer layers of this stage have yielded the following:—

Actinozoa—
    Lindstrœmia cf. *subduplicata* (McCoy) (species found in the British Llandovery).

Brachiopoda—
    Mimulus aunglokensis Reed,
    Orthis sp.

Lamellibranchiata—
    Orthonota(?) spectabilis Reed.

Gastropoda—
    Pycnomphalus sp.

Cephalopoda—
    Orthoceras aff. *tenuiannulatum* McCoy.

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[1] J. Coggin Brown. *Rec.*, XLVIII, 151 (1917).

Trilobita—
Illænus namhsimensis Reed (having affinities with *I. æmulus* Salter, of the Girvan area),
Proetus sp. "α" (having some resemblance to a Wenlock species),
,, sp. "β",
Encrinurus konghsaensis Reed (closely related to *E. punctatus*),
Calymene blumenbachi Brongn., var. (species common in Europe),
Cheirurus cf. *bimucronatus* (Murch.) (a Wenlock species),
Cheirurus(?) *inexpectatus* Reed. (close to *C. vinculum*, Barr., an Ordovician species),
Phacops (*Dalmanites*) *longicaudatus* (Murch.), var. *orientalis* Reed (abundant at Panghsapye; close to the British variety *grindrodianus* Salt., found in the Wenlock Shales of England).

Very few of the forms are local and the assemblage points to a Wenlock age. The facies of the fauna is predominantly that of northern and western Europe the only discordant element being *Mimulus*, which is a Bohemian and American genus.[1]

Commencing from the west, we find first of all a small outlier of the Lower Namhsim stage about sixteen miles north of Maymyo, the western part resting upon the old Chaung Magyi floor and the eastern upon Upper Naungkangyi beds which it has overlapped. The rocks consist of rather coarse, blue and purple, felspathic grits and sandstones, in the finer-grained layers of which fossils have been found. In the western part, where the beds rest upon the ancient floor, the basal deposits are very coarse conglomerates, the pebbles of which consist for the most part of Chaung Magyi quartzite, and to a small extent of the Mogok gneisses; these conglomerates pass up into the sandstones. This outlier, which is twenty miles distant from other outcrops, is the more interesting in that no trace of either the Lower or Upper stage of the Namhsim series can be found anywhere along the adjoining western edge of the Shan plateau. As a result presumably either of limited deposition or of localized denudation, the Plateau Limestone for sixty miles or so rests directly upon the Naungkangyis with local intercalations of the thin Zebingyi band.

Along the northern margin of the plateau, the Lower Namhsims are seen, not alwas beneath the Plateau Limestone but, due either to faulting along the base of the hills or to overlap, as outliers on the hills of Chaung Magyi rocks to the north. North of the Gokteik gorge, they cover a considerable area and form the precipitous cliffs overlooking the Nam Tang valley, extending across the boundary of the Upper Naungkangyi shales on to the highly-disturbed Chaung Magyi rocks. From Namsaw eastwards, the sandstones gradually thicken and occupy a widening area as far as the valley of the Nam Tu, north of Hsipaw. Along this valley they form low hills or cliffs, again overlapping the Naungkangyis and resting upon the old Chaung Magyi floor which had been deeply eroded before their deposition. Outliers of the sandstones, occupying the higher points of the hills are numerous.[2] Near Hkawng-hsa, the band of Namhsims bifurcates, the two branches being divided by a wedge-shaped exposure, at first of the Naungkangyis but further north of both Naungkangyis and Pangyun beds; in the Pangyun outcrop within this fork lie the mines of Bawdwin. The Namhsim sandstones of the western branch lie between the Chaung Magyis and the Pangyun beds, and have overlapped the latter as well as the Naungkangyis. The boundary with the Chaung Magyis is an overthrust fault, due no doubt to the unyielding mass of Chaung Magyi rocks to the west;

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[1] F. R. Cowper Reed. *Pal. Ind.*, New Ser., Vol. II, Mem. 3, 152 (1906).
[2] T. H. D. La Touche. *Mem.*, XXXIX, Pt. 2, 135 (1913).

it is a branch of this fault which traverses the mines and has provided a channel for the Bawdwin mineralization.[1] Felspathic bands are commoner in the western branch of this Namhsim exposure than they are in the eastern.

In the inlier S.S.W. of Kutkai in North Hsenwi, quartzitic sandstones, white or greenish grey in colour but weathering to a purplish brown, accompany rocks with Ordovician fossils. The sandstones are unfossiliferous but are thought to be probably Silurian since they occur between Ordovician beds and presumed Devonian limestone.[2]

Manaw beds.—Before describing the Upper Namhsim stage, there require mention some beds of obscure stratigraphical position some five miles north of Kyaukme railway station, a mile-and-a-quarter north of the village of Manaw. Here La Touche collected a rich assemblage of fossils "in a layer of pinkish, rather coarse-grained sandstone, not more than 6 inches thick, intercalated with somewhat shaly, purple and red sandstone." The fauna—all of it in the form of casts—includes [3] :—

Crinoidea—
  Crinoid stems, some of large size.

Brachiopoda—

Leptæna rhomboidalis Wilck.,
Orthothetes pecten Lin.,
Orthis rustica Sow.,
  ,, (*Bilobites*) *biloba* Lin.,
  ,, (*Dalmanella*) *elegantula* Dalm.,
Pentamerus (*Sieberella*) cf. *galeatus* Dalm.,
    ,, cf. *oblongus* Sow.,
Conchidium cf. *biloculare* Lin.,
Atrypa reticularis Lin.,
Spirifer cf. *radiatus* Sow.,
  ,, *sulcatus* His.,
Glassia cf. *compressa*? Sow.,
Rhynchospira (*Homœospira*) *baylei*? Dav.
Nucleospira pisum? Sow.,
Meristella? sp.

The list includes no representative of the lower Namhsim stage, and with the Upper—the Konghsa Marls—the only common species identified is the ubiquitous *Orthis elegantula*. Nevertheless, the fauna is distinctly Wenlock in character. The stratigraphical position of the beds appears to be a little below, but not far from, that of the Konghsa Marls, in which case the faunal discrepancy could only be accounted for by local variation in environment.[4] On the other hand, the lithological character of the beds and of their immediate neighbours is more like that of the Lower Namhsims, and their position not far below the Plateau Limestone might be the result of faulting. The question is of less moment if we are correct in supposing that the so-called Lower and Upper Namhsims were themselves largely contemporaneous.

Upper Namhsim stage.—The Upper Namhsim or Konghsa Marls, in spite of their small thickness, are much more widely distributed than the Lower stage. To a large extent they appear to be the deeper-water sediments of the sea whose coast was characterised by the conglomerates and sandstones of the Lower stage and La Touche's suggestion that their basal horizons may, therefore, be more or less contemporaneous with the coarser deposits, is not conflicting with palæontological evidence. The qualificatory terms "Lower" and "Upper" in these circumstances, have a somewhat artificial application to the Namhsim series.

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[1] J. Coggin Brown. *Rec.*, XLVIII, 156 (1917).
[2] Gen. Rep. *Rec.*, LXVII, 45 (1933).
[3] F R. Cowper Reed. *Pal. Ind.*, New. Ser., Vol. II, Mem. 3, 148 (1906)
[4] T.H.D. La Touche *Mem*. XXXIX, Pt. 2. 145 (1913).

The Upper Namhsim stage consists of sandy marls with layers or lenticles of very hard, compact limestone, and is exposed in the gorge of the Nam Tu north of Hsipaw and in that of the Namhsim further to the west, in both of which localities it follows conformably a full development of the Lower stage. Two exposures of the marls have been noted near the western margin of the plateau, one at Zebingyi beneath the Graptolite stage of that name, and the other four or five miles north of Pyintha. Along the northern edge of the plateau, they have been identified in a small inlier in the Plateau Limestone at Pangyu, and are poorly represented in the Gokteik gorge. Further to the northeast, a richly fossiliferous outcrop occurs close to the village of Konghsa in a cutting on the railway a mile west of Kyaukme station.

The marls of this stage, although thin, are remarkably persistent, and have been recognised elsewhere along the border of the old Chaung Magyi land-mass as far north as the mouth of the Pangyun river. In the western parts of the States, as well as in the eastern ranges, they are to be met with wherever the lower boundary of the Plateau Limestone is exposed, and east of the Man-se-le coalfield occupy a large area. This stage has yielded the following :—

Actinozoa—

Lindstrœmia sp. (much resembling *L. subduplicata* (McCoy), from the British Llandovery.)

Bryozoa—

Fenestella sp.

Brachiopoda—

Lingula lewisi Sow. (a British form),
Stropheodonta corrugatella Dav., var. (a species chiefly Ordovician but found in the Llandovery of Ayrshire),
Schuchertella pecten (Lin.) (an ubiquitous form),
Orthis (*Dalmanella*) *elegantula* Dalm.,
,, (*Platystrophia*) *biforata* (Schloth.) (has a great vertical range).

Lamellibranchiata—

Pterinea konghsaensis Reed (resembles *P. hians* McCoy, from the Aymestry Limestone).

Pteropoda—

Conularia sp.

Trilobita—

Encrinurus konghsaensis Reed.,
Calymene blumenbachi Brongn.,
Cheirurus cf. *bimucronatus* (Murch.)
Phacops shanensis Reed.,
Trachyderma cf. *squamosa* Phill.

Faunal Relationships.—The suggestion that there was a considerable overlap in the time periods of the Lower and the Upper Namhsims is supported by anomalies in the faunas. For instance, as noted by La Touche, out of the 15 identified Lower Namhsim species, six of their nearest allies are found in the Wenlock or its foreign equivalent and 9 range up into the Ludlow, while among the 28 Upper Namhsim species no less than 21 are found in the Wenlock and only —including 13 which also occur at lower horizons—are Ludlow forms. Again, two Llandovery forms, *Pentamerus* cf., *oblongus*, and a species of *Lindstrœmia* are found in the Upper Namhsim, while *Orthonota*, a typical Ludlow shell, occurs low down in the Lower stage. It is best, therefore, to consider the Namhsim fauna as a whole, in which case it must be looked upon as equivalent to the Wenlock or Middle Silurian, with an admixture of species from lower and higher horizons.

Zebingyi Series.—The Zebingyi series is very restricted in area, and of but slight thickness even where most highly developed.[1] It is exposed as a thin interrupted band along the western margin of the plateau approximately parallel to the cart road passing up to Maymyo from Mandalay, between the Naungkangyi beds beneath and the overlying Plateau Limestone into which it passes up with no sign of unconformity. The most complete exposure, however, is seen below the nearer of the two outliers of Plateau Limestone west of Pyintha, where the Zebingyi series crops out on both sides of a shallow syncline. On the west the beds consist of the following in descending order :—

3. White, flaggy, thin-bedded, unfossiliferous limestones, passing upwards into the Plateau Limestone.
2. Some 80 feet of dense black, earthy limestone with thin partings of black shale, characterised by *Monograptus dubius*, *Tentaculites elegans* in enormous numbers and the small pteropod *Styliolina lævis*.
1. Grey, thin-bedded limestones mutually separated by layers of light-coloured shale overlying similar limestones with thinner, more shaly, carbonaceous, intercalated layers crowded with *Tentaculites*, the whole about 200 feet thick.

In the eastern limb of the syncline, the grey, thin-bedded limestones are replaced by a hard, nodular, massive, lenticular limestone, crowded with weathered casts of *Orthoceras*, while the black, earthy limestones are much reduced in thickness and most of the graptolites, which are here more numerous and better preserved, are found in light grey shales ; the two outcrops are continuous to the north. The following forms have been found in the Zebingyi beds[2] :—

Graptolitoidea—
  Monograptus dubius Suess (a typical Wenlock fossil but ranging to Lower Ludlow ; found in Britain, Sweden, the Harz and Bohemia).
  ,, *riccartonensis* Dalm. (found in Wales.)

Actinozoa—
  Lindstrœmia sp.

Crinoidea—
  Crinoid stems.

Brachiopoda—
  Stropheodonta comitans Barr., var. *subimbricata* Reed.
  Meristina ? sp.,
  Meristella cf. *recta* Barr.[3]
  Pentamerus (*Clorinda*) aff. *krasnopolskii* Tschern.[3]

Lamellibranchiata—
  Modiolopsis shanensis Reed, (almost identical with a Bohemian form),
  Vlasta ?sp. (resembling Bohemian forms),

Pteropoda—
  Tentaculites elegans Barr., (in vast numbers ; characteristic of the Devonian of Bohemia)
  ,, cf. *ornatus* Sow. (species found in the Wenlock of Britain),
  Styliolina cf. lævis (Richter).

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[1] T. H. D. La Touche. *Mem.*, XXXIX, pt. 2, 163—181 (1913).

[2] F. R. Cowper Reed. *Pal. Ind.*, New Ser., vol. II, Mem. 3, 147 (1906) ; *Ibid* vol. VI Mem. I. 89,98 (1915).

[3] *Rec.*, LXII, 249 (1929).

Cephalopoda—
Orthoceras aff. *commututum* Gieb. (species found in the Lower Devonian of the Harz),
,, aff. *eichwaldi* Barr. (species found in Bohemia).

Trilobita—
Phacops (*Dalmanites*) *swinhoei* Reed (closely allied to a group of species characteristic of the Bohemian stage G, and of the south European zoogeographical province of the Devonian),
,, *shanensis* Reed.

Beds of black calcareous shales occur to the north and east of the last fossiliferous outcrop, which is situated about a mile north of Taungmoi, just below the Plateau Limestone, but have so far yielded no organic remains. Near the village of Pangyu, on the northern edge of the plateau, some black limestones were discovered near the base of the Plateau Limestone and from them were collected[1] :—

Brachiopoda—
Atrypa marginalis Dalm. (of wide distribution in the upper Ordovician and Silurian),
,, (*Atrypina*) ? *sub-globularis* Reed (resembling Bohemian forms),
Meristina ? sp.

Lamellibranchiata—
Dualina ? sp. (with considerable resemblances to Bohemian Silurian forms),
Lunulicardium aff. *amabile* Barr. (species found in the upper Silurian of Bohemia).

Cephalopoda—
Orthoceras aff. *nicholianum* ? Blake

Annelida—
Trachyderma cf. *squamosa* Phillips.

The doubtful *Meristina* is the only form found common to this locality and Zebingyi. *Tentaculites* has not been observed at all, but the exposure requires further investigation and may well prove to be one of the Zebingyi stage.

On the road from Lashio to Möng-pyen, at mile-post " 17-4 ", from a gently folded series of dark purplish, fissile, earthy shales which have interbedded layers of reddish ironstone and grey, tough, horny limestone, Dr. Cowper Reed collected a few poorly-preserved fossils, none of which has been so far recorded from the Zebingyi beds. No trace of graptolites or *Tentaculites* has been observed in these beds, which are probably somewhat higher stratigraphically than those near Zebingyi, but the close affinity or identity of the species with well-known Lower Devonian forms elsewhere makes it reasonable to assign the beds to a slightly higher horizon of the Zebingyi stage. The following have been identified[2]:—

Lamellibranchiata—
Cypricardinia semisquamosa Reed.
Avicula aff. *insidiosa*? Barr. (species found in stages G and H of the Bohemian Devonian).

Cephalopoda—
Platyceras sp.

Trilobita—
Entomis pelagica Barr. (a European Lower Devonian species),
,, cf. *phalanga* Kegel (species found in the Lower Devonian of Europe).

As a whole, the Zebingyi fauna, in which we may include the assemblage just described as well as that of the Pangyu beds, is remarkable in that it comprises Silurian graptolites and the typically Lower Devonian *Tentaculites elegans*, and is evidently a transitional fauna between the two systems. The assemblage collected on the road from Lashio to Möng-pyen is entirely Lower Devonian in aspect. La Touche describes the Zebingyi beds as passing up into the Plateau Limestone.

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[1] F. R. Cowper Reed. *Pal. Ind.*, New Ser., Vol. II, Mem. No. 3, 147 (1906).
[2] *Rec.*, LXII, 252 (1929).

Relationships of The Namhsim series.—The geographical relationship of the Namhsim fauna and of the Zebingyi fauna have now to be considered. In the case of the Namhsim, on comparison with the fauna of the Himalayan Silurian we find the same remarkable want of concordance as is shown by the Ordovician of the two regions ; four or five forms only—and these all ubiquitous species—are common to the two areas, and only one of the species peculiar to Burma, *Encrinurus konghsaensis*, is represented by an allied and widely ranging species in the Himalayan Silurian, *E. punctatus*. The contrast in composition between the faunas of the two areas also persists, that of Burma being characterised by the presence of graptolites, the scarcity of corals, and the profusion and variety of trilobites, that of the Himalaya by the presumed absence of graptolites, the preponderance of corals at certain horizons, and the more moderate numbers and varieties of the trilobites. This difference in facies probably indicates a difference in sedimentation which may account to some extent for the marked disagreement between the two assemblages. The relationship of the Namhsim fauna with north European faunas is closer even than it is in the case of the Ordovician, and it is evident that the connection with north Europe and the barrier shutting off the Himalayan sea continued into Silurian times.

Relationships of the Zebingyi series.—In the case of the Zebingyi fauna we note a change which is of interest and importance, for its facies is no longer that of northern and western Europe but is unmistakably Hercynian. Out of the 24 species described, no less than 16 are identical with or closely allied to forms from Bohemia or the Hercynkalke of the Harz, and several of these are distinctive forms. The connection with Bohemia does not appear to have been directly through the Ural Mountains, since only two of the peculiar types from the Zebingyi beds—one of them a doubtful genus and species, *Vlasta* sp., the other *Entomis pelagica*—are allied to or identical with any described from the Russian area. The Zebingyi series evidently corresponds, to a large extent, to the Muth Quartzite of the Himalaya.

SOUTHERN SHAN STATES.

Equivalents of the Panghsa-pye series.—The Silurian system has been identified by Coggin Brown and Sondhi in the Southern Shan States, both to the west and east of Taung-gyi. The Graptolite stage has been noted in several localities but has been more closely observed at Panghkawkwo, near Loi-lem some thirty miles southeast of Taung-gyi, where a richly fossiliferous band includes two horizons belonging, the one to the upper Valentian, and the other to the higher Salopian. The Graptolite beds of this locality, which are in places severely crushed, consist of white or light grey, fissile shales often with dark grey laminae ; rarely the shales are brown or light purple in colour, when they are more thickly bedded[1]. In this same band of lower Palaeozoics, another belt of the Graptolite shales is seen further to the east in a closely packed series of folds involving Ordovician rocks as well as higher members of the Silurian. In places, the shales are deeply decomposed to clay ; some of the faded purple varieties contain fragments of trilobites. The following are the graptolite determinations of Miss Elles :—

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[1] *Rec.*, LXVII, 144 (1933).

Glyptograptus serratus E. & W.,
Monograptus sedgwicki McCoy,
,, *regularis* Törnq.,
,, *distans* Lapw.,
,, *lobiferus* McCoy.,
,, *convolutus* His.,
,, *undulatus* E. & W.,
,, *concinnus* Lapw.,
,, *millepoda* McCoy.,
Climacograptus scalaris His.,
Retiolites sp.

In addition, *Monograptus circularis* E. & W. has been collected from a bleached shale in a neighbouring locality, east of Loi-lem.

Further north, on the western flank of Loi Samhpu in Möng Pawn, the Graptolite band has again been recognised in the form of a carbonaceous shale, yielding abundant specimens of *Monograptus* of the same species as those in the Panghkawkwo bed, as well as a few *Diplograptus*.

Some distance to the northeast of Taung-gyi, about twelve miles north of the town of Möng Kung in the State of that name, graptolites, including *Monograptus* and *Diplograptus*, were found by Cecil Jones ; here white and yellowish sandy shales, and some nearly black shales which they overlie, all contain graptolites.

The best known exposoure of the Graptolite beds in the Southern Shan States was discovered by Sondhi as a narrow band averaging a furlong in width along the western and southern edge of the Pindaya outcrop and separating the Pindaya deds from the Plateau Limestone. The band has been traced southwards as far as Wabya Taung, but further east and along the south western limits of the Pindaya anticline it appears to be overlapped by the Plateau Limestone (Permian)[1] northwards it is perhaps represented at first by certain crushed, splintery slates, and it is definitely recognisable again in Lawksawk State. The bulk of the band consists of carbonaceous shale and slate with a rich graptolite fauna. In Wabya Taung, these black beds, which rest upon the yellow mudstones of the Ordovician (Pindaya), are overlain by soft, light-coloured shales. The Wabya Taung band of graptolites probably includes at least three separate zones, one of which is identical with that found at Panghsa-pye in the Northern Shan States—the zone of *Monograptus cyphus* of the Lower Valentian. In the Wabya Taung band *Orthograptus* is the most prolific genus, *Climacograptus* is quite common, while *Monograptus* is comparatively scarce ; the complete list of forms determined by Miss Elles is as follows[2]:

**Monograptus cyphus* Lapw.,
,, *incommodus* Törnq.,
,, *sandersoni* Lapw.,
,, *concinnus* Lapw.,
,, *revolutus* Kurck.,
,, *difformis* Törnq.,
,, *gregarius* Lapw.,
,, *jaculum* Lapw.,

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[1] *Rec.*, LXVII, 212 (1933).
[2] *Pal. Ind.*, New Ser., Vol. XXI, Mem. 3, 105-106 (1936).

Monograptus decipiens Tõrnq.,
,, *lobiferus* McCoy.,
,, *convolutus* His.,
**Orthograptus vesiculosus* Nich.,
,, *mutabilis* E. & W.,
**Climacograptus medius* Tôrnq.,
,, *tõrnquisti* E. & W.,
,, *rectangularis* McCoy.,
Glyptograptus tamariscus Nich. var.,
,, ,, Nich. var. *incertus*

Mesograptus magnus ? Lapw.

*Species found in the Pangsha-Pye Graptolite bed of the Northern Shan States.

A very small exposure of the Graptolite band, consisting of bleached shales containing the Valentian assemblage: *Monograptus fimbriatus* Nich., *Orthograptus mutabilis* E. & W., *Climacograptus medius* Törnq. and *C. innotatus* Nich., has been recognised on the eastern slope of the hill on which Kyawktap pagoda stands. The same band, from which specimens of *Orthograptus* have been obtained, is seen in the more southern of two small hills at the northern end of the He-ho plain.

At the southern end of the He-ho plain, on Mebya Taung, three graptolite horizons are recognisable in the Graptolite stage which includes two thin beds of limestone, and is underlain by a thin brownish phacoidal limestone resting on limestones of the Mawsön series (Ordovician). In the lowest of the three horizons the species found recall those of Wabya Taung and the Pindaya margin further north ; as identified by Miss Elles they are :—

Monograptus gemmatus Barr.,
,, *concinnus* Lapw.,
,, *jaculum* Lapw.,
,, *gregarius* ? Lapw.,
,, *tenuis* Portl.,
Climacograptus törnquisti Elles & Wood,
,, *medius* Törnq.

According to palaeontological evidence, the next oldest bed is a bleached shale weathering to a light soil, containing faint graptolite remains among which the following four have been determined :

Monograptus tenuis Portl.,
,, *millepoda* McCoy,
Climacograptus törnquisti Elles & Wood,
,, *scalaris* His.

The youngest horizon is composed of pale bleached shales in which the graptolites occur in greater profusion and in better preservation than in the horizon just described ; in it have been found :—

Monograptus sedgwicki McCoy.,
,, *tenuis* Portl.,
Climacograptus scalaris His.

Stratigraphically the mutual relationships of these horizons are obscure.

Between the Yawnghwe and Kun-lon plains, an outcrop of Silurian of appreciable size includes some light-coloured sandy shales with badly-preserved and apparently unidentifiable graptolites, seen to the west of Okpo-ywa ; from their diplograptid nature these fossils would seem to indicate Lower Silurian horizons.[1]

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[1] J. Coggin Brown and V. P. Sondhi. *Rec.*, LXVII, 228 (1933).

One-and-a-half miles west of the village of Chaung-gauk, the same outcrop has yielded the following specimens poorly preserved in a bleached mudstone : *Monograptus millepoda* McCoy, *M. jaculum* Lapw., *Orthograptus* sp. and *Climacograptus medius* Törnq[1].

These and other graptolite occurrences, the examination of which is not yet concluded, prove that the Valentian series is abundantly represented by several zones in many localities in the Southern Shan States, as it is also in the Northern States, western Yunnan and other parts of China. The lowest zone is that of *Monograptus cyphus*, the next higher that of *M. sedgwicki*, and above this comes the zone containing *M. lobiferus*, which is present also in the Panghsa-pye area of the Northern Shan States. These three zones are all represented in the Wabya Taung exposure. The zone of *Monograptus sedgwicki* has not been found in the country between Kalaw and Taung-gyi, nor has it yet been recognised in the Northern Shan States ; in the latter region, however, the Ludlow stage of *Monograptus riccartonensis* occurs in the Zebingyi series.

Equivalents of the Namhsim series.—There is good reason to believe that the Namhsim series is also present in the Southern Shan States. Southeast of Taung-gyi, in the neighbourhood of Namhkok, are poorly exposed, much weathered brown, red-stained shales and light-coloured sandstones, which strongly recall this series ; in places the rocks have undergone lateritization with the production of limonitic iron ore[2].

Associated with the Graptolite band on the western flank of Loi Samhpu in Möng Pawn is an unfossiliferous sequence, some members of which are repeated consisting of :—soft, fine-grained, fawn or brownish grey sandstones alternating with sandy shales ; hard, slaty grey or greyish blue limestones with occasional patches and streaks of brown shale ; alternations of slate-blue, splintery and slabby limestones with sandy mudstones ; highly-cleaved and contorted, light greenish grey and purple slates ; and bleached, purple, sandy shales. The last mentioned are in contact with the Graptolite bed, and show disturbance. Beyond the Graptolite bed some brown-stained, greyish shales have yielded a small collection of fossils, the determination of which has given the following[3] :—

Graptolitoidea—
 Monograptus cf. *vulgaris* Wood.

Brachiopoda—
 Lingula exornata Reed,
 Orthis (*Dalmanella*), sp.,
 Triplecia cf. *woodlandensis* Reed,
 Leptelloidea cf. *segmentum* Lindstr.,
 Atrypina cf. *disparilis* (Hall),
 Parastrophinella cf. *reversa* (Bill).

Owing to their flattened-out condition the specimens are difficult to determine but they appear to indicate a Salopian age ; to the beds containing them has been given the name of the Loi-lem stage (Facies 1).

Further east, Silurian limestones are seen on the hillsides on both sides of Loi-lem and have given rise to the usual system of cauldron valleys. The commonest types are of various shades of grey, hard, compact, very fine in grain and with a splintery fracture; on weathering, wavy layers are developed and give a cellular surface to the rock. More rarely the limestones are pink, green or purple; occasionally they are well banded in alternating colours. Among them pink, phacoidal varieties identical with those above the Panghkawkwo graptolite bed are recognisable. East of Loi-lem, the phacoids in the limestone are described as attaining two inches in length, one inch in width, and $\frac{1}{4}$ inch in thickness, and as being separated from each other by shining black films. Interbedded with the limestones of this locality are bands of mudstone with small brachiopods and other remains. These beds form what is known as the Loi-lem stage (Facies 2) and are characterised by a peculiar new genus of brachiopods to which the name *Loilemia* has been given. The small fauna at present known is as follows, the affinities of most of the species being with Salopian forms.[1]

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[1] F. R. Cowper Reed, *Pal. Ind.* New Ser., Vol. XXI, Mem. 3, 108 (1936).
[2] J. Coggin Brown and V. P. Sondhi. *Rec.*, LXVII,137 (1933).
[3] *Pal. Ind.*, New Ser., vol. XXI, Mem. 3, 108 (1936).

Actinozoa—
- *Palæocyclus* ? sp.,

Brachiopoda—
- *Plectodonta loilemensis* Reed,
- *Loilemia proxima* Reed,
- *Merista* ? sp.
- *Glassia* ? sp.,
- *Nucleospira* cf. *pisum* (Sow.).

Lamellibranchiata—
- *Lunulicardium* sp.

Northwards, towards Wan-pong, these limestones and the graptolite beds are involved in a closely-packed series of folds in which the Ordovician rocks also participate. Some of the limestones have thin seams of siderite. Further east in this belt of Lower Palaeozoics, the limestones disappear and a lower type of topography marks the coming-in of brown, marly mudstones interbedded with greyish white, papery shales, the former breaking up into small spheroidal fragments and containing casts of small broken crinoid stems. These are followed by fine-grained sandstones, dark, sandy shales, and thin bands of bleached purple mudstones with infrequent crinoid stems, a succession which is repeated further on. No fossils have yet been identified in these sandy and argillaceous beds but lithologically, and especially in their strongly felspathic character, as well as in their considerable thickness, they much resemble the Lower Namhsim series.

At the southern end of the He-ho plain, the Graptolite band is accompanied by soft sandstones and phacoidal limestones, the sequence being overlapped by the Plateau Limestone.

In central Lawksawk, Silurian beds equivalent to both the Namhsim sandstones and the Zebingyi beds have been brought into contact with Chaung Magyi rocks and lower members of the Ordovician by a N.-S. fault.[2]

Equivalents of the Zebingyi series.—Separating the Yawng-hwe and Kun-lon plains is a considerable outcrop of Silurian, which is split into two by a narrow N.-S. band of the Plateau Limestone. To the West of this younger band the rocks consist of dark grey limestones often containing *Orthoceras*, and sometimes of sheared, pale grey limestones blotched with brown, pale pink, phacoidal limestones, and reddish brown sandstones and shales. From the shales Sondhi obtained many fragments and one practically complete specimen of a trilobite belonging to the genus *Phacops* (*sens. str.*) and named by Cowper Reed as a new species, *Phacops ponensis* ; this trilobite is similar to *P. shanensis* of the Northern Shan States. Perhaps identical with the latter is another species, *P.* cf. *sternbergi* Barr. from the same beds. From the presence of these trilobites, and from the occurrence also of *Tentaculites*, it is inferred that the beds probably represent the Zebingyi stage.

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[1] *Pal. Ind.*, New Ser. Vol. XXI, Mem. 3, 112—113 (1936).

[2] *Rec.*, 72, 67 (1937).

To the east of the small Plateau Limestone band, a steady, easterly-dipping sequence occurs as follows :

4. Grey, quartzitic sandstones, weathering brown, with intercalated bands of hard, bluish white shales ;
3. Dark grey limestones, interbedded with the above sandstones ;
2. Dark grey limestones with *Orthoceras* and crinoid stems, and a few bands of a pinkish black, soft, sandy mudstone crowded with *Tentaculites elegans*, Barr., associated with which, both here and elsewhere, are numerous specimens of *Styliolina clavulus* (Barr.) and *Entomis* cf. *phalanga* Keg, [1]
1. Thin bands of pink, phacoidal limestone, interbedded with shales (rarely seen).

A few miles south of this section, light-coloured, sandy shales—perhaps the equivalent of the last mentioned bed (No. 1) in the more northerly succession—were found to contain badly preserved graptolites ; since these consist predominantly of diplograptid forms, their parent rock would appear to be considerably lower in the Silurian sequence than the Tentaculites beds and to have been pushed over the latter by an overfold or thrust. Above the graptolite bed are brown, sandy, micaceous, unfossiliferous mudstones, and further on, following a long concealed tract, are pink and brown phacoidal limestones with a few grey bands.[2]

The *Tentaculites elegans* horizon also occurs in the Mebyataung area, to the south of the He-ho plain, where it contains in addition *Monograptus vomerinus* Nich.[3] The same beds with innumerable specimens of *Tentaculites* and isolated specimens of a brachiopod resembling *Meristina*, are seen on the eastern flank of the Zawgyi basin in Lawksawk State. The Zebingyi beds in this State overlie the Namhsim sandstones.[4]

The trilobite bed of Panghsa-pye and the Konghsa Marls of the Northern Shan States have not been recognised in the more southern region.

YUNNAN.

Two out of the nine pre-Plateau Limestone horizons described by Coggin Brown a few miles to the south of Yung-ch'ang Fu, in the Shih-tien district of Yunnan, west of the Salween, contain Silurian fossils ; beds of this system have evidently, therefore, been folded up with the Ordovician. The lower horizon consisting of tough, black, carbonaceous and finely micaceous shales or slates, contains abundant *Climacograptus* and has yielded :—

Monograptus incommodus Törnq.,
,, *regularis* Törnq.,
,, *tenuis* ? Portl.,
Climacograptus rectangularis McCoy,
,, *törnquisti* Ell. and Wood,
Mesograptus modestus Lapw. ?

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[1] *Pal. Ind.*, New Ser., Vol. XXI, Mem.3, 18 (1936).
[2] J. Coggin Brown and V. P. Sondhi. *Rec*,, LXVII, 228 (1933).
[3] *Pal. Ind.*, New Ser., Vol. XXI, Mem. 3, 118 (1936).
[4] *Gen. Rep. Rec.*, LXXI, 64 (1936) ; *Gen. Rep. Ibid.* LXXII, 66 (1937).

The higher horizon, consisting of a tough, fine-grained, greenish grey or pinkish, flaggy slate, weathering yellow, has yielded the following graptolites, *Monograptus lobiferus* being the most abundant :[1]

Monograptus sedgwicki Portl.,
,, *lobiferus* McCoy,
,, *tenuis* Portl.,
,, *leptotheca* Lapw.,
,, *atavus* Jones,
,, *jaculum* Lapw.,
,, *concinnus* Lapw.,
,, *gemmatus* Barr.,
Glyptograptus serratus Ell. and Wood,
,, *tamariscus* Nich., var. *incertus* Ell. and Wood,
Climacograptus scalaris His.,
,, *törnquisti* Ell. and Wood,
Gladiograptus perlatus Nich.,
Mesograptus magnus Lapw.?

Both beds evidently belong to the Llandovery stage, the lower horizon probably to the zone of *Orthograptus vesiculosus* or perhaps the base of *Monograptus gregarius*, the upper to the base of the zone of *Monograptus sedgwicki*. The lower-lying of the two outcrops occurs in faulted and contorted, scattered exposures, and contains the younger of the two faunas. The other outcrop, nearer the top of the hill, is some 70 feet thick, faulted against Ordovician rocks below, and contiguous in some unknown way to Ordovician rocks above ; this exposure has yielded representatives of both the faunas mentioned above.

From a hill a few miles northwest of Shih-tien, Messrs. Yin and Lu have more recently collected Silurian fossils from five successive zones, as follows:[2]

5. Abundance of *Pristiograptus tumescens*, *P. vulgaris curtus*, and *P. dubius*.	(Ludlow series ; zone of *Pristiograptus tumescens*).
4. *Pristiograptus colonus*, *P. varians*, *P.* aff. *dubius*, and a small *Orthis*.	(Ludlow series ; zone of *Linograptus nilssoni*).
3. *Pomatograptus mccoyi*, *P.* aff. *mccoyi*, *Streptograptus nodifer*, *Spirograptus turriculatus*, *S.* aff. *spiralis*, and *Petalograptus* sp.	(Upper Valentian, upper part of the zone of *Spirograptus turriculatus*).
2. *Pristiograptus nudus*, *Pomatograptus halli*, *Streptograptus runcinatus*, *Str.* aff. *dextrosus*, *Spirograptus* aff. *spiralis*, and *Petalograptus* sp.	(Basal Upper Valentian ; lower part of the zone of *Spirograptus turriculatus* or band of *Rastrites maximus*).
Mesograptus modestus, *Climacograptus* aff. *medius et rectangularis*, and *Orthograptus* sp.	(Lower Valentian ; probably the zone of *Orthograptus vesiculosus*).

The lowest of these five zones is in all probability equivalent to the lower of the two zones established from Dr. Coggin Brown's collections. It is curious that none of the species identified in the upper of the two zones established by Dr. Coggin Brown has been found among the collections of Messrs. Yin and Lu. None of the five zones established by Yin and Lu has been recognised in Burma.

A species of *Monograptus* was found by Coggin Brown in a series of black, micaceous slates, ten miles to the south of Shih-tien, southeast of the small Pai-ma valley.[2]

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[1] J. Coggin Brown. *Rec.*, XLVII, 226 (1916).
[2] *Bull. Geol. Soc. China*, XVI, 53 (1936).

PALÆOGEOGRAPHY.

The early part of the Silurian period in many parts of the northern hemisphere was characterised by an encroachment of the sea which had begun at the close of the Ordovician. The open character of this sea was responsible for the uniformity of fauna which has left its relics in the various regions of this hemisphere. Towards the end of the Lower Silurian epoch, this marine transgression gave place to an almost universal enlargement of land areas. The Middle Silurian was a continental phase, exemplified in the Salina red beds of North America but represented nearly everywhere else by an erosional interval of great length. Finally the Upper Silurian was marked by a renewed advance of the sea.

Towards the end of the Lower Silurian epoch, owing to the general rise of land areas, the waters of the world became incompletely separated into three main oceans similar to those which characterised early Ordovician times, *viz.* (i) the Atlantic, (ii) the Arctic or Boreal, and (iii) the Pacific. The Atlantic included the sea occupying north Europe and an almost isolated basin, the Bohemian sea, covering southern Europe. The great Irkutsk basin of Siberia formed part of the Boreal ocean. It is from the Peri-Arctic ocean that the Himalayan and Burmese Silurian faunas, with the exception of that of Zebingyi at the very end of the period, were derived. As remarked by Dr. Cowper Reed, " with the exception of one species of *Mimulus* occurring in the Namhsim sandstones, the fossils of the Panghsa-pye and Namhsim beds have Peri-Arctic affinities, and no Bohemian types are present."[1]

In Asia, the Silurian of Turkistan, central Asia, Lake Balkash, and the Himalaya, appears to have belonged to one great arm of the sea which stretched southeastwards from north Europe and the Arctic, and then eastwards along the Himalayan geo-syncline, expanding finally into a large basin which covered parts of north Burma, Yunnan, Tonkin and central China. Along this path migrated the mixture of Boreal and Atlantic organisms which characterise the Silurian of India, Burma and China. The American element of these Asiatic faunas was probably introduced through some transient connection with the Pacific waters. While both the Lower and Upper Silurian are present over much of this extensive waterway, the Middle subdivision is represented by the usual hiatus. The rich Silurian fauna of central China, in spite of its individual character, betrays its European affinities ; though many of the corals are peculiar, several European species of both corals and brachiopods have been described from the beds.[2] The meagre Lower Silurian fauna of the Mien-tien group in eastern Yunnan has a shore facies and is unlike any from other parts of China, from Indo-China, from Burma or from the Himalaya ; its similarity to that of the Medina Sandstone of eastern North America may be partly an expression of similar physical environment, as suggested by Grabau, but seems to indicate some marine connection between the two areas.

The rich graptolite fauna of Llandovery and Lower Wenlock age from the Northern and Southern Shan States, containing as it does many European species of *Monograptus*, is an excellent illustration of the extremely wide distribution of the pelagic members of the Silurian fauna. One common and continuous

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[1] *Rec.*, XL, 26 (1910).

[2] Gen. Rep. *Rec.*, XLV, 109 (1915)

Silurian ocean seems to have spread round the northern hemisphere, and to have included the old interior sea of North America.

With regard to the Zebingyi beds, which show premonitions of the Devonian in their fauna, opinion is necessarily undecided. The fauna has a Bohemian element and is described by Cowper Reed as completely Mediterranean, with no north European forms.[1] Even the lithological as well as the palaeontological character of these beds is said to be strikingly Bohemian. The cause of this remarkable influx into Asia and of the exclusion of the normal north European successors of the pre-existing fauna is not yet known. Whatever their precise age may be, Grabau concludes that there is no positive evidence of the invasion of this area by a European sea either in Upper Silurian or Lower Devonian times. Such being the case, the Zebingyi area must have formed part of the marine embayment which in Upper Silurian times covered a small area in eastern Yunnan, southwest Kwangsi and perhaps also Tonkin. Since the fauna of the Zebingyi beds exhibits a close resemblance to that of the Manlius Limestone of New York and the Lower Monroan of Michigan, this embayment is thought to have come from the Indian Ocean region, a suggestion which receives support from the absence in the embayment of the normal marine Upper Silurian fauna of the northern and western regions. The typical Zebingyi pteropods, *Tentaculites elegans* Barr. and *Styliolina clavulus* Barr. are described from Tonkin, where their beds are assigned to the Devonian. Further a field, *Monograptus dubius* Suess has been found in Victoria, and one of the new trilobites from the Zebingyis of the Southern Shan States, *Phacops* cf. *sternbergi* Barr. has a close Australian relative. The Silurian fauna of Australia is, in fact, characterised by a mixture of species from the two zoological provinces.

Dr. Du Toit calls attention to the fact that the Muth Quartzite of the Himalaya has its close equivalent in many other marginal parts of the old Gondwana continent, especially when the supposed drifted portions of the latter are restored to the most likely position they originally occupied. Over large portions of the periphery of the continent "the slow subsidence of the peneplain and the reworking by water of the waste thereon led to the formation of pale unfossiliferous grits and sandstones of uniform siliceous character, often strongly false-bedded. With steady sinking this type of accumulation became extended inwards across the faintly inclined coastal region in a covering of considerable thickness and enormous extent unconformably upon the highly eroded basement." Such a deposit is represented in Spiti and Afghanistan, and has an enormous development in western Africa. Something very like it is also present in British and Dutch Guiana and eastern Venezuela (Roraima sandstones), and its recognition is unquestionable in the lower part of the Amazon syncline, in Bolivia, in western and southern Argentina, in western and southern Brazil, in Uruguay, in the Falkland Islands and in Cape Colony (Table Mountain Sandstone). The lowest beds of the Reefton Devonian in New Zealand are also quartzitic. As Dr. Du Toit remarks "from the huge areal extent and presumed manner of accumulation of this arenaceous facies upon a broad subsiding continental margin, its age cannot everywhere be the same". Its age appears to vary from Upper Silurian to Lower Devonian. Du Toit suggests that "wind played an important part in its accumulation by blowing inland quartz-grains pulsated on an extremely flat shore, to which they were returned by rivers". "A cold moist climate is indicated, ...indirectly by the generally bleached nature of the sands......and lack of plant life, and directly by a fairly widespread glacial zone in the southwestern Cape." Off Gondwanaland deposition was continuous from the Silurian to Devonian, in contrast to conditions off the continent of the northern hemisphere, Laurasia, where sedimentation normally began with the Devonian, save over limited areas.

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[1] *Rec.*, XL, 27 (1910).

CHAPTER XVIII.

DEVONIAN AND POSSIBLE EQUIVALENTS OF NORTHERN INDIA.

Occurrences. **Kangra, Bashahr and Rupshu. Byans. Chitral :** Lower Devonian of Showar. Shur ; Middle Devonian of the Baroghil Pass ; Upper and possibly Lower Devonian, Reshun area. Upper Devonian, Baroghil Pass ; Koragh spur, Shah Janhli Pass and Kosht ridge ; Owir gorge, Yakhdan, Lasht and Petus ; Yasin, the Hunza valley, and the Wakhan range. Ak Baital, Russian Turkistan. **The Khyber Pass. Afghanistan. Jaunsar and Nagthat series of Simla, Dehra Dun, Tehri Garhwal and British Garhwal ;** Stratigraphical position; Jaunsars of the Simla area ; Nagthat series of Chakrata, Mussoorie, Tehri Garhwal and British Garhwal. **Tanawal (Tanol) series.** Hazara ; The Himalaya-Hazara syntaxis ; Southwest Kashmir.

Occurrences.—So far as is known, the Devonian is not represented by fossiliferous rocks either in Peninsular India or in the Salt Range, but is definitely present in Chitral, Afghanistan, Persia, the Pamirs, southeastern Kashmir (Rupshu), the northeastern Punjab (Kangra district and Bashahr State), the border country of Almora and Nepal, and the Northern and Southern Shan States of Burma. It is possible that beds of this age are represented by one or more of the unfossiliferous formations in Hazara, the central and western parts of Kashmir, the Simla and Chakrata section of the Himalaya, and in Southern Burma (Tenasserim). As already explained, the Muth Quartzite of the Himalaya-Hazara syntaxis, Spiti, Kashmir, Ngari Khorsum (Tibet) and Kumaon is probably mostly Devonian in age but has been described under the heading of Silurian since it appears to bridge the gap between the two systems and to include the uppermost horizons of the older. A description of the Devonian in Burma will be included in the following chapter.

KANGRA, BASHAHR AND RUPSHU.

In the valleys of the Lipak and Yulang rivers in Bashahr, the Muth Quartzite passes up, through about 80 feet of shaly beds and narrow bands of quartzite into some 300 feet of siliceous and shaly limestone containing four hard nodular coral-bearing bands, varying from 1 foot to 3 feet in thickness. The lowest bed of the limestone is made up of a hard siliceous matrix containing badly crushed corals, crinoids and brachiopods ; these fossils include numerous examples of a large form referable to the genus *Orthothetes* and resembling *O.* (*Schellwenella*) *umbraculum* Schloth., together with *Atrypa aspera*, and species of *Orthis* and *Cyathophyllum.* Occurring above this horizon, the coral bands appear to be composed entirely of a species of *Cyathophyllum*, the material of the original forms having been almost completely replaced by calcite and silica. The following is a list of all forms so far obtained from these limestone bands, as determined by Dr. Cowper Reed[1] :

Crinoidea—
  Crinoid stems.

Actinozoa—
  Cyathophylloid coral.

Bryozoa—
  Idiostroma yulangensis Reed.

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[1] *Rec.* XLI, 110 (1911).

Brachiopoda—
 Atrypa aspera Schloth.,
 Orthothetes aff. *crenistria* Phill.,
 Productella or *Strophalosia* sp.

The above limestone is found also in the area of the Spiti river sources and, though greatly crushed, contains brachiopods similar to those found in Bashahr, including examples of the same *Orthothetes.* The same limestone is probably represented in the Muth section of the Pin valley, but here contains no determinable fossils. Where present, this limestone is overlain by limestones and quartzites of Lower Carboniferous age.[1] To the complete section, so well seen in the Lipak valley, from the top of the Muth Quartzite up to the upper limit of the limestone and quartzite group, Hayden gave the name of "Lipak series". There is little doubt that the upper part of this series, an alternation of limestones and quartzites, belongs to the Lower Carboniferous, and that the lower, between the base of the limestones and quartzites and the top of the Muth Quartzite is referable to the Devonian ; the small fauna suggests the lower horizons of the Upper Devonian or the upper part of the Middle Devonian, from which it seems more than probable that much at least of the Muth Quartzite should also be included in this system.[2] Hayden was inclined to regard part of the Muth Quartzite as a conformable bridge between the Upper Silurian and the Lower Devonian, since the formation lies conformably upon beds of Llandovery or possibly Wenlock age containing *Pentamerus oblongus.*

In this part of the Himalaya the lower or Devonian portion of the Lipak series which, as we have seen, consists principally of a splintery siliceous limestone with two or three Devonian fossils, is frequently wanting in Palæozoic sections, having been removed by the erosion which took place between Carboniferous and Permian times.

BYANS.

A few fossils collected from a dark compact limestone in the Kali valley ("Tera Gadh camp"), between Nepal and Almora, indicate so far as they are determinable either the lower stage of the Upper (Frasnian) or the upper stage of the Middle (Givetian) Devonian. The following have been identified by Dr. Cowper Reed.[3]

Actinozoa—
 Favosites cf.*b asaltica* Goldf.[4]
Brachiopoda—
 Atrypa reticularis var. *desquamata* Sow.,
  ,, *aspera* (Schloth.),
 Pentamerus cf. *sublinguifer* Maurer.,
 Camarophoria cf. *phillipsi* (Dav.),
 Wilsonia cf. *omega* Whidb.,
 Orthis aff. *bistriata* Tschern.
Lamellibranchiata—
 Pterinopecten or *Aviculopecten* (sp.)
Cephalopoda—
 Orthoceras sp.

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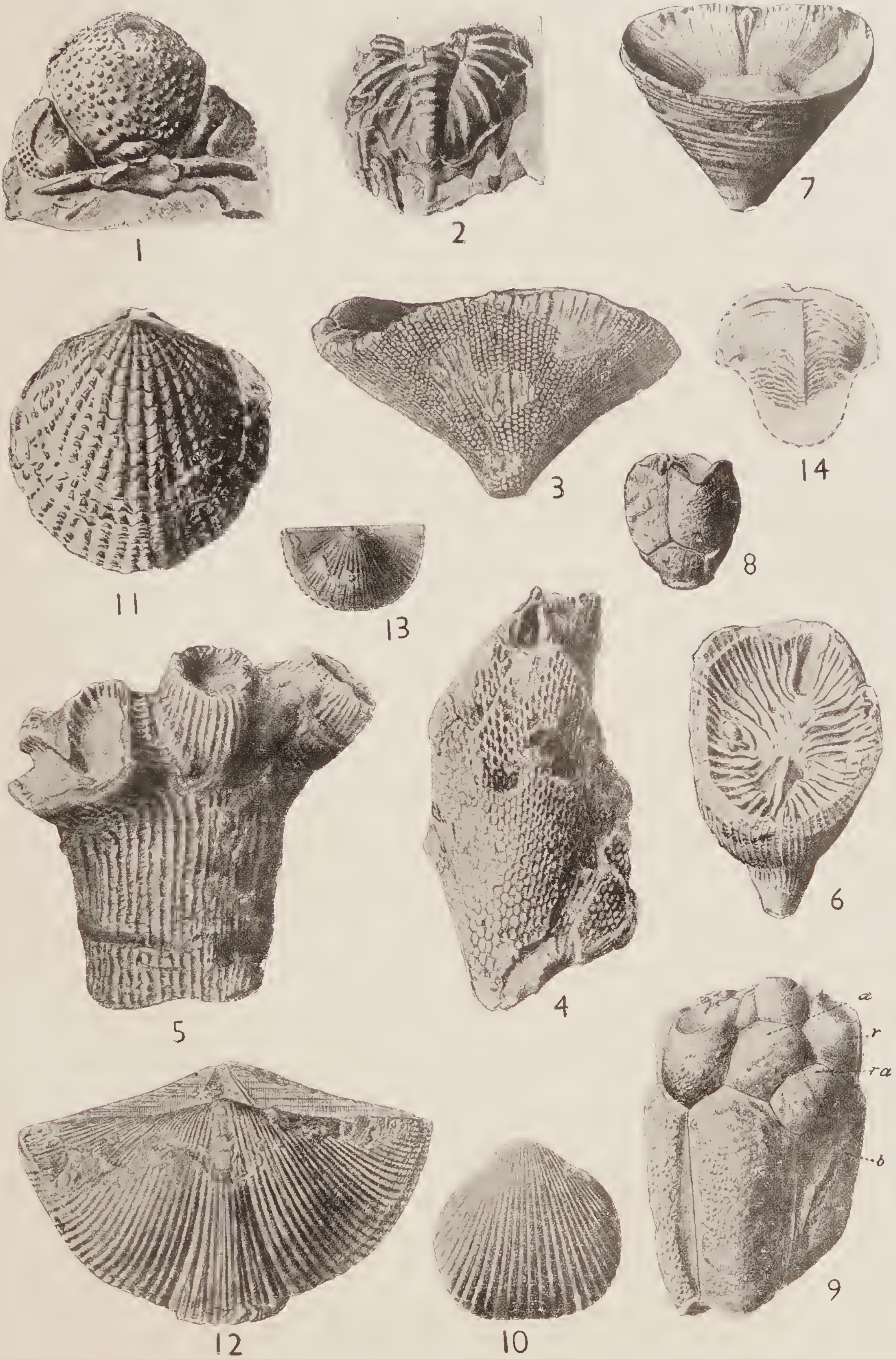
[1] H. H. Hayden. *Mem.*, XXXVI, 44 (1904).

[2] F. R. Cowper Reed. *Rec.*, XLI, 110 (1911).

[3] *Rec.*, XLI. 107(1911). Two other forms which may have come from this same locality are ; a species of *Fenestella* and a coral much like *Favosites cervicornis* Blainv.



DEVONIAN FAUNA.

1. *Phacops latifrons* (Bronn). 2. *Dalmanites (Asteropyge) koraghensis* Reed. 3. *Hemitrypa oculata* Phillips. 4. *Polypora hundlestoni* Reed. 5. *Cyathophyllum (Thamnophyllum) multizonatum* Reed. 6. *Aulacophyllum looghiense* Schluter. 7. *Calceola sandalina* Lamarck. 8. *Storthingocrinus fritillus* (Wirtgen and Zeiler). 9. *Bactrocrinus birmanicus* Reed. 10. *Uncinulus* var. *transiens* Reed. 11. *Atrypa spinosa* Hall var. *chitralensis* Reed. 12. *Spirifer verneuili* Murchison. 13. *Chonetes subcancellata* Reed. 14. *Bellerophon shanensis* Reed.

G. S. I., Calcutta.

CHITRAL.

Lower Devonian Showar Shur.—A dark, rather foetid, compact or partly crystalline and occasionally fissile limestone from Showar Shur near the Baroghil Pass, in the Yarkhun valley of Chitral, has yielded the following lower Devonian fauna collected by Lieut. I. H. Grant and determined by Dr. Cowper Reed :

- Crinoidea—
  - Crinoid stems.
- Actinozoa—
  - *Striatopora* cf. *vermicularis* McCoy.
- Bryozoa—
  - *Fenestella* sp.,
  - *Thamnicella* ? sp.
- Brachiopoda—
  - *Spirifer* aff. *primævus* Stein.,
  - ,, cf. *robustus* Barr.,
  - ,, aff. *canaliferus* Valenc. ?,
  - *Athyris* cf. *subconcentrica* d' Arch. & Vern.,
  - *Pentamerus* (*Sieberella*) *sieberi* von Buch,
  - *Uncinulus* cf. *bureaui* Barrois,
  - *Liorhynchus* sp.,
  - *Orthis* cf. *præcursor* Barr., var. *sulcata* Scup.,
  - *Stropheodonta phillipsi* Barr.,
  - *Orthothetes hipponyx* (Schnur),
  - *Chonetes* aff. *embryo* Barr.,
  - *Productella* ? sp.
- Lamellibranchiata—
  - *Pterinæa* sp.
- Gastropoda—
  - *Polytropus guillieri* Oehl. ?
- Trilobita—
  - *Proetus chitralensis* Reed.

These fossils, some of which are in nearly perfect preservation indicate a Lower Devonian age and comprise an intermixture of species possessing either Bohemian or north European affinities ;[1] the Bohemian element is said to predominate, but a similar assemblage has been observed in the Lower Devonian of the Urals and Altai, and it was from the Ural gulf that the Ak Baital fauna of Russian Turkistan was probably derived.

Middle Devonian of the Baroghil Pass.—From one of the limestones in the Baroghil Pass was obtained a poor and crushed specimen of a *Spirifer* which, if correctly referred to *Spirifer mediotextus* or *S. subcuspidatus*, would indicate a Middle rather than an Upper Devonian age for the bed.[2]

Upper and Possibly Lower Devonian, Reshun Area.—Some thirty miles to the northeast of the town of Chitral, in the vicinity of Reshun, a conspicuous conglomerate and some shales of Lower Tertiary age, according to Mr. Tipper, have been let down between two faults of great throw against Devonian beds on the northwestern side and against the Chitral Slates of Upper Palæozoic age on the southeastern.[3] Generally speaking, the beds which abut on the conglomerate and shales to the northwest are composed of siliceous limestone and quartzite both of which, in the words of Hayden "recall the upper part of the Silurian and lower part of the Devonian systems as seen further east in the Himalaya, and may include the Muth Quartzite, which is such a persistent feature of Himalayan stratigraphy".[1] Occasionally, this limestone and quartzite, which occur beneath beds with Upper Devonian fossils, are cut out by the fault and the Upper Devonian fossiliferous limestone is then brought up against the Tertiary beds. Along the fault line, between the Reshun Conglomerate and the supposed Upper Silurian to Lower Devonian succession, isolated masses of crystalline limestone occur at intervals; sections of *Hippurites* in these prove that they belong to the Middle Cretaceous.[2]

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[1] *Rec.*, XLI, 87 (1912) ; see also J. Coggin Brown. *Rec.*, XLV, 271 (1915) : and F. R. Cowper Reed. *Pal. Ind.*, New Ser., Vol. VI, Mem. 2, p. 2 (1922).

[2] *Pal. Ind.*, New Ser., Vol. VI, Mem. 2, p. 128 (1922).

[3] The conglomerate was at first thought to be the equivalent of the Blaini (see *Geol. Mag.* Dec. IV, Vol. IX, 3-8 (1902)).

Southwestwards, the great fault is described as curving almost in a semicircle before resuming its former direction, this curvature being accompanied by the complex folding and cutting out of the Upper and Lower Devonian.[3] Near the village of Neuk, Fusulina Limestone beds of Carboniferous age lie almost flat and have the appearance of having been let down by block faulting between normal Devonian beds and a shale series known as the Sarikol Shales and thought by Tipper to form part of the Upper Devonian.[4] Up the valley S.S.E.' wards from the village of Buni, the unfossiliferous Lower Devonian limestones have been completely overfolded and faulted on both sides against narrow bands of the Tertiary Reshun conglomerates and shales.

The lower siliceous limestone with its accompanying quartzite, together with the younger overlying limestone, are again exposed at the top of a high hill behind Shugram in the Reshun area. The lower limestone here often contains crinoids, while the upper is dark and bituminous and has yielded a comparatively large fauna, consisting chiefly of corals and brachiopods, of Upper Devonian age. Towards Mastuj, the lower siliceous limestone passes into a brown limestone full of crinoid stems, accompanied by quartzite. On the ridge which turns the Chitral river just below Koragh, there is a good section of the Upper Devonian beds. Sometimes whole bands of rock, as much as 6 feet in thickness, are composed of *Spirifer murchisonianus* de Kon.;[5] below these are bands of coral and under these again a shaly bed with *Atrypa spinosa*, var. *chitralensis* Reed,[6] and trilobites. The limestone of this sequence is described by Cowper Reed as being somewhat bituminous.[7] Each of the fossiliferous bands is separated from the others by a thin band of quartzite. Higher up the ridge, the fossiliferous beds are underlain by dark shales passing down into brown and grey limestone full of corals. The latter is evidently the lower limestone of the Reshun area, for below it is a thick mass of pale yellow and white quartzite, which Hayden was tempted to regard as the equivalent of the Muth Quartzite of the Himalaya.[8] The Upper Devonian limestone opposite Reshun and above Shugram is overlain by the Sarikol Shales, a thick series of paper-shales, needle-shales and quartzite; in the shales a thin bed of crinoid limestone has been observed. Both the limestone and the shales are repeated by a fault near Luni. The following is a list of the fossils obtained from the Shugram and Koragh localities[9]:

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[1] *Rec.*, XLV, 284 (1915).

[2] *Rec.*, LIV, 56 (1922).

[3] *Rec.*, LV, 38 (1923).

[4] At first looked upon as probably Carboniferous (H. H. Hayden. *Rec.*, XLV, 287 (1915)).

[5] At first identified as *Spirifer verneuili Rec.* XLV, 288 (1915).

[6] At first identified as *Atrypa aspera* (*Ibid.*).

[7] *Pal. Ind.*, New Ser., Vol. VI, Mem. 2, p. 3 (1922).

[8] *Rec.*, XLV, 288 (1915).

[9] Cowper Reed. *Pal. Ind. New-Ser.*, Vol. VI, Mem. 2 (1922).

Actinozoa—
Cyathophyllum torquatum Schlüter, var. *orientalis* Reed,
* ,, *heterophylloides* Frech,
,, (*Heliophyllum*) *cylindricum* Schulz,
,, (*Hexagoniophyllum*) *sedgwicki* Edw. & H.,
,, (*Thamnophyllum*) *multizonatum* Reed,
* ,, ,, *trigeminum* (Quenst.),
,, (*Phacellophyllum*) *cæspitosum* Goldf.,
,, (*Campophyllum ?*) *chitralense* Reed.
Phillipsastræa monticola Reed,

* *Pachypora cristata* Blum.,
,, *polymorpha* Goldf., var. *viator* Reed,
Striatopora devonica Schlüter, var. *chitralensis* Reed, [1]
,, *angulosa* Gürich, var. *koraghensis* Reed,
,, aff. *tchichatschewi* von Peetz,
Alveolites suborbicularis Lam., var. *hudlestoni* Reed,
,, [*Plagiopora ?*] *ramosa* Roemer,
Plagiopora subtuberosa Reed,
* Hydrozoa—
Thecostegites bouchardi (Mich.),
Stromatoporella aff. *granulata* Nich.,
Actinostroma aff. *clathratum* Nich.
Cystidea—
Crinoid stems.
Bryozoa—
Polypora hudlestoni Reed,
,, *mcmahoni* Reed,
Lioclema nivale Reed,
Fistulipora shugramensis Reed,
Eridotrypa sp.,
Hederella aff. *canadensis* Nich.

Brachiopoda—
**Craniella obsoleta* (Goldf.),
Orthis (*Schizophoria*) *striatula* Schloth., var.,
Kayserella (?) *koraghensis* Reed (cf. *Orthis venusta* Schnur),
* *Stropheodonta* (*Douvillina*) *dutertrii* (Murch.), var. *asiatica* Reed,
Productella fallax (Pand.), var. *chitralensis* Reed,

Uncinulus (*Uncinulina*) *koraghensis* Reed at first indentified as *Rhynchonella* sp.
,, ,, ,, , var. *pentagonalis*, Reed,
,, ,, ,, , var. *transiens*, Reed,
,, ,, ,, , var. *ponderosa*, Reed,

Athyris acuminata Drev., var. *asiatica* Reed,
,, *chitralensis* Reed,
,, ,, , var. *pseudoglobularis*, Reed,
,, ,, , var. *gentilis*, Reed at first identified as (*Authoris concentrica*)
,, *gurdoni* Reed,
,, *hudlestoni* Reed,
* ,, *puschiana* (de Vern.),
,, cf. *triplesioides* Oehl,

Atrypa spinosa Hall, var. *chitralensis* Reed at first identified as (*Atrypa aspera*)
Spirifer anossofi de Vern.,
* ,, *bifidus* Roemer,
* ,, *murchisonianus* de Kon., [2]
,, *orbelianus* Abich,
* ,, *reshunensis* Reed,

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[1] At first identified as *Favosites* cf. *cristata* (see Hudleston. *Geol. Mag.*, Dec. IV, Vol. IX, p. 51 (1902)). Many of the forms in Hudlestone's list seem to have been incorrectly identified (see *Pal. Ind.*, New Ser., Vol. VI, Mem. 2, p. 124 (1922).

[2] Dr. Cowper Reed finds it almost impossible to establish any constant differences between *Spirifer murchisonianus*, *S. brodi*, *S. archiaci*, *S. tenticulum* and *S. verneuili*, "for they seem to be branches from one common stock with intermediate gradations and variations. Murchison's *S. verneuili* is known to many geologists, especially those in America, under Sowerby's name of *S. disjunctus*; whatever name is employed, it is a notably widespread species".

* *Spirifer verneuili* Murch,
* ,, ,, , var. *archiaci* Murch.[1]
,, ,, , var. *mastujensis* Reed,[2]
,, cf. *pachyrhynchus* de Vern.
Lamellibranchiata—
Actinopteria victrix Reed,
**Aviculopecten ingriae* (de Vern.),
Myalina sp.
Gastropoda—
Euomphalus cf. *circularis* Phill.
Cephalopoda—
Orthoceras sp.
Chaetopoda—
**Spirorbis omphalodes* Goldf.
Trilobita—
Phacops aff. *latifrons* Bronn,
Dalmanites (*Asteropyge*) *koraghensis* Reed.

According to Cowper Reed, this fauna is Frasnian, *i.e.*, it belongs to the lower part of the Upper Devonian, though several of the forms occur also in the overlying Fammenian stage. The species above marked with an asterisk compose an assemblage characteristic of the Frasnian, and many of the others are closely allied to, comparable to, or merely varieties of, well-known European Upper Devonian species.[3] The species of *Spirifer* are especially characteristic, and *Spirifer murchisonianus* occurs in similar abundance in the Upper Devonian of the western Urals. In addition to Belgium and northern France, where the name of Frasnian originated, this type of fauna has been recorded from the Ural mountains, from the Iberg Limestone of the Harz, from Turkistan, Afghanistan, Persia, Armenia, parts of Asia Minor, the Tian Shan, various parts of Siberia, and China including Yunnan.

Upper Devonian, Baroghil Pass.—A narrow band of ferruginous rocks, striking E.-W. and faulted in among the Fusulina limestones of the Baroghil Pass section, thickens when traced eastwards and becomes fossiliferous. Similar fossiliferous rocks are seen resting on the Permian-Triassic beds (Pamir Limestone) of the Shawitakh Pass. On the road to Showar Shur, the same rocks are observable, occupying the centre of an overfold which has led to the reduplication of the Fusulina and other limestones, the latter forming high scarps to the north of Showar. From the fossils obtained therefrom, these ferruginous rocks appear to be of Upper Devonian age. They occur again in the hills on the right bank of the Karambar valley, and again on the right bank of the large glacier south-east of Showar Shur; the structure in these areas is of considerable complexity.[4] In the hills to the west of the Baroghil Pass, these ferruginous beds are very fossiliferous and are separated from the Carboniferous and the Permian-Trias by a fault.

Koragh Spur, Shah Janali Pass and Kosht Ridge.—Towards the end of the Koragh spur, the fossiliferous beds are overlain by quartzite which seems to be a repetition of the rock further down in the section. There may be a fault through the spur, and its higher parts are worthy of search in the hope of finding more of the Palæozoic group including the Lower Devonian Limestone of Shower

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[1] Identical with a form from Afghanistan.

[2] At first identified as *Spirifer extensus*.

[3] *Pal. Ind.*, New Ser., Vol. VI, Mem. 2, p. 126 (1922); see also *Geol. Mag.* Dec. IV. Vol IX, 3-8, 49-58, and (Jan. & Feb. 1902).

[4] Gen. Rep., *Rec.*, LVI, 46 (1924).

Shur. Opposite Koragh, the Mastuj river is joined by another broad stream which drains Murikho and Turikho ; this is a large valley running up to the snowy peaks fronting Kala Panja. The valley is the structural continuation of that of the Mastuj river from Koragh downwards. In the upper Turikho valley, in the neighbourhood of the Shah Janali Pass, there commences a series of black slates, grits and quartzites, with some conglomerate bands. The outcrop gradually increases in breadth owing to the intercalation of epidotised trap rocks, of masses of conglomerate composed of white rounded quartz pebbles in a red ferruginous matrix, and also of some detrital rocks of volcanic origin. Traced to the southwest, these rocks pass into softer black shales and quartzites forming the Kosht ridge and lithologically similar to the Sarikol Shales. The rocks of the Kosht ridge are generally unfossiliferous but occasionally contain *Orthoceras* and crinoid stems. One band of limestone, forming part of these beds, has yielded numerous fossils, an examination of which suggests that the beds are of Upper Devonian and not Lower Carboniferous age as had at first been supposed. Tipper suggests that they may be the continuation of the ferruginous beds of the Baroghil section[1].

Owir Gorge, Yakhdan, Lasht and Petus.—The Upper Devonian between Reri and Owir, along the Owir gorge, has yielded a number of good fossils. As at the Baroghil Pass, there is a considerable thickness of beds above the horizon of the Koragh spur and Shugram which contain typical Upper Devonian fossils. Above Buni, the Devonian beds appear to cross the Mastuj river, which here flows from east to west, and to run along the high ridge between Turikho and the Yarkhun valley.[2] Just above the small village of Yakhdan, rocks similar to the Reshun conglomerate, grit and crinoid limestone, all considerably metamorphosed, are found on the right bank of the river. Behind Lasht, which is also on the right bank of the river, the crinoid limestone series, presumably representing the Devonian of Reshun, underlies a very thick sequence of black slate and white quartzite which forms the high ridge north of the village and extends up to the snow-line where it is in contact with intrusive granite. This probably corresponds to the Sarikol Shale series of the Shugram area. These rocks—conglomerates, limestones and slate, with intrusive granite—continue with an equatorial strike all the way to Petus, the last village in the Yarkhun valley. Above Petus, the prevailing rocks in the Yarkhun valley are slate and quartzite, with some limestone and granite in the high hills on either side.

Yasin, the Hunza Valley, and the Wakhan Range.—It is probable that the Devonian and other members of the Palæozoic are present in Yasin,[3] and in the Hunza valley.[4] The southwestern corner of Chinese Turkistan is occupied by shale and slate belonging to the Sarikol Shale series. In the high hills, the series is chiefly slaty, owing to the neighbourhood of intrusive granite and other igneous rocks ; where the igneous rock is some distance away needle shales take the place of the slates and vividly recall the much young
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[1] Gen. Rep., *Rec.*, LVI, 47 (1924).
[2] H. H. Hayden *Rec.* XLV, 289 (1915).
[3] See Gen. C. A. McMahon and W. H. Hudlestone, *Geol. Mag.* Dec., IV. Vol. IX, 3-8 (1902).
[4] C. A. McMahon. *Q. J. G. S.*, LVI, 337 (1900).

(Mesozoic) Spiti Shales of the Himalaya. The series extends to the west and is clearly the continuation of that seen from the Baroghil and Shawitakh Passes. It was found by Hayden in the Wakhan or Nicholas range, between the Great Pamir and Wakhan whence it appeared to be perfectly continuous into the south-western extremity of the Taghdumbash Pamir. Here and there bands of crystalline limestone run through it. In the Pamirs this series is much intruded by trap.[1]

Ak Baital, Russian Turkistan.—The Devonian occurs below the Ak Baital Pass in the Pamirs in the form of carbonaceous shale with thin courses of limestone and occasional bands of sandstone. Both limestones and sandstones, more especially the former, have yielded a fauna of widely different facies from that of Chitral; so far as known, not a single species is common to the two areas. Brachiopods, especially rhynchonellids, greatly predominate, both as regards number of species and number of individuals, while corals and cephalopods are practically absent. The most abundant fossil is *Camarotœchia baitalensis* Reed, and varieties thereof; next in importance come species of *Spirifer*, the most plentiful being *S. pamiricus* Reed. Corals and cephalopods are practically absent. The following have been determined by Dr. Cowper Reed :[2]

Actinozoa—
Blothrophyllum ? sp.
Brachiopoda—
Orthis (*Rhipidomella* and *? Dalmanella*) sp.,
A. *Productella arctirostrata* Hall ?,
A. ,, *baitalensis* Reed,
A. ,, *hirsuta* Hall,
A. ,, *lachrymosa* Hall, var. *lima* Conr.,
A. ,, ,, var. *stigmata* Hall,
,, *membranacea* (Phill.),
,, *robertsoni* Reed,
,, *subaculeata* (Murch.), var. *pamirica* Reed,
,, *sublaminata* Reed,
Strophalosia compta Reed,
A. ,, cf. *muricata* Hall,
,, cf. *truncata* Hall,
Chonetes mcmahoni Reed,
,, *nana* de Vern.,
A. *Camarotœchia baitalensis* Reed,
,, ,, , var. *transversalis* Reed,
,, ,, , var. *comitata* Reed,
,, *guillieri* Oehl., var. *pamirica* Reed,
Pugnax acuminata (Mart.) var.,
Camarophoria (?) *formosa* Schnur, var. *martialis* Reed,
A. ,, (?) *tschernyschewi* Toll, var. *mutata* Reed,
,, (?) ,, , var. *semiformosa* Reed,
A. ,, (?) *subplana* Reed,
Liorhynchus (?) *longinquus* Beyr.,
Bifida (?) *problematica* Reed,
Spirifer pamiricus Reed, (close to or identical with the Russian *S. anossofi* de Vern. found in the *Stringocephalus* stage),
A. ,, ,, , var. *parilis* Reed (identical according to some palaeontologists with *Sp. verneuili* Murch.)
,, cf. *jeremejevi* Tschern.,

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[1] *Rec.*, XLV, 300 (1915).
[2] *Pal. Ind.*, New Ser., Vol. VI, Mem. 2, p. 128 (1922).

A. *Ambocœlia gregaria* Hall, var. *asiatica* Reed.

Lamellibranchiata—
- *Streblopteria* cf. *devonica* (Frech),
- *Pseudamusium* ? sp.,
- *Leptodesma* sp.

Gastropoda—
- *Pleurotomaria* cf. *voronejensis* de Vern.,
- *Naticopsis* ? sp.

The brachiopods are closely allied to or identical with forms in Persia, Europe and America. The fauna is characterised by species with decided American affinities (marked "A" in the list), and is in this respect brought into relationship with faunas from Ferghana, Chinese Turkistan, the island of Kotelny and the western slope of the Urals; with one horizon in the latter, correlated with the *Stringocephalus* stage of western Europe, the general similarity is marked. While the Chitral Devonian, therefore, possesses a fauna of a western European type, the Pamir fauna is much closer to that of the Boreal province, to which the Urals belong, and is unlike that of any beds in western Europe. Cowper Reed's opinion is that the fauna should be regarded as belonging to the Upper Devonian rather than to the uppermost Middle Devonian, while Grabau suggests that it is a passage fauna between the two.

The fossiliferous beds described above are underlain by coarse pisolitic limestones containing small Rhynchonellidae and associated with hard compact limestones containing silicified corals.

THE KHYBER PASS.

Some large blocks of yellow, sandy limestone, observed near Jamrud by C. S. Fox were found by Tipper to contain species of *Productus* and *Spirifer* indicative of a Devonian age; they are thought to have come from the limestone scarp east of Shahgai.[1] This limestone may be identical with one found in the Bazar valley and also near Parachinar.

AFGHANISTAN.

In the Koh-i-Baba and the Hindu Kush of Afghanistan, the graphitic slates of the Kalu series, representing some part of the lower Palæozoic, are overlain by a bed of hæmatite, followed by a limestone which at the foot of the Kotal-i-Hajigak (Hajigak Pass), contains a Devonian fauna.[2] In the neighbourhood of Kalu, the hæmatite forms a thick bed capping the high ridge which runs north-east towards Ghorband. On the southern flank of this ridge, the hæmatite is overlain by slate which in turn is succeeded by grey limestone with calcite veins and numerous small crystals of hæmatite; this is associated with a fossiliferous black thin-bedded limestone. Fossils from a small outcrop of the last-mentioned bed at the foot of the Hajigak Pass, chiefly brachiopods, belong to an Upper-Devonian fauna of the same type as that found in the Shugram and Koragh localities of Chitral, and include, according to Cowper Reed :—

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[1] *Rec.*, LIX, 15 (1926).

[2] H. H. Hayden. *Mem.*, XXXIX, 23—25 (1911).

Actinozoa—
- *Cyathophyllum* cf. *hypocrateriforme* Goldf.,
- *Striatopora* ? sp.

Brachiopoda—
- *Spirifer verneuili*, var. *archiaci* Murch.,
- *Wilsonia cuboides* (Sow.)
- *Rhynchonella* (? *Wilsonia*) cf. *dumonti* Goss.,
- *Camarotœchia* cf. *omaliusi* Goss.,
- *Productella subaculeata* (Murch.),
- *Strophalosia productoides* (Murch),
- *Stropheodonta interstrialis* (Phill.) ?

Some of the specimens are well preserved but the majority are poor, the most abundant being the variety of *Spirifer verneuili* and *Productella subaculeata*.[1] The grey limestone is of Lower Carboniferous age.

From Ghorband, the hæmatite, associated with a red limestone, extends along the lower slopes on the left side of the valley, northeastwards across the lower spurs of the Hindu Kush, up the Panjshir valley, into the hills of Kohistan. In the Ghorband valley, the hæmatite bed is overlain by a crystalline series of slate, schist and limestone, which presumably represents the Hajigak series; the only fossils found in the limestone which, like the other beds, is metamorphosed and quite crystalline, are crinoid stems, occasionally in profusion.[2]

JAUNSAR AND NAGTHAT SERIES OF SIMLA, DEHRA DUN, TEHRI GARHWAL AND BRITISH GARHWAL.

Stratigraphical position.—The name Jaunsar, as restricted by Pilgrim and West, was applied to a series mapped in the Simla area and at first called by them the Jagas series. Generally speaking, it underlies the Chails which have been thrust over it. It often shows a higher degree of metamorphism than the Simla Slates, and was provisionally regarded at first as older than and thrust over the latter, and assigned to a later section of the Purana. As a result of further work to the southeast, it has been suggested by Auden that the Jaunsar series is younger and not older than the Simla Slates, *i.e.*, that it is stratigraphically as well as tectonically above them. According to this idea, it is a shallow-water, conglomeratic phase, probably of epi-continenta character, intervening between the Simla Slates and the Upper Carboniferous Blaini, but frequently missing from that position owing to the unconformity beneath the Blaini.[3] This scheme would correlate the Jaunsars of Simla and their supposed equivalents around Chakrata—the Nagthats—with the slates and quartzites of the Lower Tanawal series of the Hazara-Kashmir area, and place them somewhere in the middle of the Palæozoic (? Devonian). In the Simla region, the outcrops of the Jaunsar beds are seen skirting the Chail exposures and occurring between them and the Simla Slates; for long distances a narrow band of the Blaini (or Mandhali?) separates the Jaunsars from the Simlas. The Jaunsar series, as delimited by Pilgrim and West, includes little more than the middle division of the system to which Oldham gave the same name, *i.e.*, the "red quartzites and slates" among which occur the highly characteristic conglomerates. though these are not specifically mentioned by Oldham. Pilgrim and West excluded the limestones and the doubtful volcanic beds, and their restricted use of the term Jaunsar is adopted in this work.[1]

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[1] *Rec.*, XLI, 103(1911).
[2] H. H. Hayden. *Mem*,. XXXIX, 23-25 (1911)).
[3] *Rec.*, LXV, 132 (1931).

Jaunsars of the Simla area.—In the Simla area, the following is a typical sequence of the Jaunsar beds which, however, are described as varying rapidly in character from place to place and containing no conspicuous horizons :[2]

Chail Thrust........
(5) Pale sub-schistose slates.
(4) Much-crushed micaceous slates and phyllites.
(3) Purple phyllites and conglomerate.
(2) Purple, green and grey quartzites or grits, pebbly in their upper horizons.
(1) Slates with slaty cleavage and vein quartz.
(Boulder beds, perhaps belonging to the Mandhali.)
(Simla Slates.)

A conglomerate in the Jaunsar near Kuffar shows the effects of intense crushing, the pebbles, consisting mostly of hard quartzite, having been sheared and drawn out, and the principal mineral changes localised about the surfaces of friction. Other crushed conglomerates in the same locality present the appearance of a silvery, purple, talc schist or phyllite with somewhat lenticular pebbles of quartz. Elsewhere, bands of conglomerate are observable in a purple, current bedded " quartzite " ; in this typical shallow-water deposit pebbles of milk-white quartz, averaging about 1 inch but ranging sometimes up to 3 or 4 inches in diameter, form the bulk of the conglomerate and are very conspicuous, while in addition there are pebbles of purple quartzite and fragments of slate, the latter so abundant locally as to give the rock a semi-schistose character. A peculiar green slickensiding is characteristic of the Jaunsar beds of the Simla area, especially in the basal phyllites.

As in the case of the Chail series, the dynamic factor has been the preponderating influence in the metamorphism of the Jaunsars. Pilgrim and West remark that the distinctness as regards metamorphism of the Chails from many of the beds of the Jaunsar series is not superficially notable. The latter, for instance, includes true slates with the original bedding markedly oblique to the present cleavage. There are, however, appreciable differences in the case of the arenaceous rocks. In the Chail series, these include true quartzites with granoblastic structure—a mosaic with no interstitial spaces. In the Jaunsars, these beds invariably show signs of the original clastic structure, and the constituent grains of quartz have suffered no recrystallisation. In fact, the Jaunsar beds, since they show no siliceous cement, are better described as sandstones or grits, or at the most incipient quartzites ; in places they are characterised by marked current-bedding. The presence of true phyllites in the Jaunsars witnesses to a locally low-grade metamorphism sufficient to produce sericitic mica in the argllíaceous members of the formation. Attention has already been drawn to the difference in grade between the metamorphism of the Jutogh beds on the one hand and that of the Chails and Jaunsars on the other. There is a marked contrast in the other direction, according to Pilgrim and West, with the Simla series, the argillaceous components of which are often not even in the condition of true slates, in spite of the fact that they are probably older than the Jaunsar deposits. Such metamorphic differences are evidently untrustworthy for stratigraphical purposes, unless considered along with the tectonic history and position of the beds compared, especially in relation to any neighbouring igneous intrusion, and after due recognition of the fact that the degree of metamorphism of a series of rocks may vary appreciably in the Himalaya when the formation is traced laterally from one area to another.

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[1] Oldham's upper division probably includes Jutogh hornblende schists, members of the Chail series and one or two true Jaunsar beds ; his lower division, as we have seen is now included in the Chail. Oldham first called his " Jaunsar system " the " Chakrata series " (*Rec.*, LXVI, 129 (1932)). Auden, working in the Chakrata area where Oldham established his classification, at first used the term Jaunsar for a more extended succession than that included by Pilgrim and West, and divided the series into three stages, the Lower or Mandhali, the Middle or Chandpur, and the Upper or Nagthat. On joining up with the work around Simla, however it has been found that the Chandpur rocks are most probably the equivalents of the Chails, while the Nagthat beds appear to represent the whole of the Simla Jaunsar series. The Mandhalis may prove to be the equivalents of the Blaini, but their age has not yet been satisfactorily determined. Oldham mapped the Nagthats as Mandhalis.

[2] Guy E. Pilgrim and W. D. West.*Mem.*, LIII, 15 (1928).

To the southwest of Jutogh, the double band of Jaunsars together with the intervening band of Simla slates probably forms an overturned iso-anticline dipping towards the northeast; the boundary between the two series in the overturned limb is interpreted by Auden as the commencement of the Giri thrust. To the southwest, this anticline is followed normally, according to this observer, by an inverted syncline invloving the Blaini, Infra-Krol and, further along, the various members of the Krol series. The Jaunsars are well exposed on each side of the Giri river, southeast of the town of Chail, where they are separated from the Simla Slates by a narrow band of the Blaini, or what is its possible equivalent, the Mandhali series. Similarly, a little further north, the beds at first on both sides of the Mangred Khala are assigned to the Blainis or the Mandhalis, to which conglomeratic formation also belongs the small outcrop mapped as Jaunsar on the left bank of this stream. Where traversed by the Giri river, the Jaunsar beds must be quite 1,500 feet thick, consisting mainly of massive white and purplish green quartzitic sandstones and purple phyllites.

The Jaunsar series is seen again in the Mahasu ridge northeast of Simla, and to the south of Phagu where it attains considerable dimensions;[1] in the latter locality, the Chail beds dip beneath the Jaunsars which are here almost horizontal and comprise purple conglomerates full of quartz pebbles and very like the conglomerates in the Ashni river section, massive white quartzitic sandstones, purple phyllites, and a green and purple schistose slate extensively used for roofing purposes in the neighbouring villages. Further northwest, the series becomes attenuated and is probably represented by the steep, southwesterly-dipping, massive, white quartzite of the Mashobra-Mahasu ridge, beneath which the Chail beds are still seen to be dipping.

Nagthat series of Chakrata, Mussoorie, Tehri Garhwal and British Garhwal.—The Nagthat series, in the northern limb of the Chakrata syncline, appears to lie conformably on the Chandpur beds, often with a basal conglomerate; in the south, it is thought to overlap the Chandpurs with marked unconformity. The characteristic rocks of this stage are sandstones, arkoses, quartzites, grits, conglomerates, clay-slates and phyllites showing purple and green colours. The variation in metamorphism is great, from soft clay-slates to talcose phyllites or from sandstones to schistose quartzites. The arenaceous rocks are strongly current-bedded and ripple-marked and some of the sandstones are pyritic. As in the Jaunsar conglomerates of the Simla area, the pebbles of such rocks are composed of vein-quartz often stained red or purple, of purple and pale quartzite, and of purple and green slate or phyllite. Eastwards, green tuffaceous sandstones are developed, as well as quartzites, some of which are agglomeratic and resemble the gritty facies of the Blaini when relatively free from pebbles and boulders. Associated with the quartzites, slates and phyllites in this stage are also some boulder beds, with angular boulders of dark slate and greenish quartzite—types common in the Jaunsar series—lying in a gritty matrix. It is to the Jaunsar rocks of the Simla area that the Nagthat series would appear to correspond.

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[1] Gen. Rep., *Rec.*, LXII, 165 (1929).

According to Auden, the metamorphism of the Jaunsar as well as of other rocks of the Krol belt is typically *epi*-grade. Some of the quartz schists of the Jaunsar or Nagthat series have been sufficiently altered for the clastic structure to be almost obliterated, and mosaics of recrystallised quartz are frequent, but such changes are never found uniformly throughout the whole body of the rock. Allusion has already been made to the wide variation in the degree of metamorphism. Sandstones, quartzites and quartz schists are all found in close association; single beds of quartzite may be distinguished by extreme permeation by vein-quartz due to crushing, while adjoining beds are free from such veining. Similarly clay-slates, slates, phyllites and chlorite-schists also occur in close proximity to one another, the green beds being specially susceptible to alteration.

The Jaunsar arkoses, which contain plagioclase and tourmaline, witness to the presence of a pre-Jaunsar granite, the pegmatite of which perhaps furnished the vein-quartz of the Jaunsar pebbles. This granite is thought to have been an earlier granite than that of the Chaur-Lansdowne-Dudatoli intrusion.

Locally the Jaunsar series seems to have been completely eroded away previous to the deposition of the Blaini, which in local sections lies directly, though with no visible discordance of bedding, upon the Simla slate series.

In the Mussoorie area, the syncline of Blaini, Infra-Krol, Krol and Tal rocks is in contact on the northeast with the Nagthat series, upon which the Blaini unconformably rests, the whole of this sequence together with the underlying Chandpurs forming the Krol *nappé*; the Nagthats themselves cut across the Mandhalis and Chandpurs.[1] The Krol *nappé* lies between the Krol Thrust below and the Garhwal Thrust above, and is overlain by the Garhwal *nappé*. In other parts of the Dehra Dun district, the Nagthats have been thrust over Nummulitic and younger Tertiary beds (Miocene), along the Krol Thrust. Both the Chandpur and Nagthat beds of the Krol *nappé* show a marked increase in metamorphism from southwest to northeast.[2] On the southwest side of the Mussoorie syncline for example, the mottled green and purple Nagthat sandstones are described as similar in appearance to the Vindhyan; on the northeast side, the beds lose their purple colour and become schistose chlorite-sericite quartzites. Southeastwards along the strike also, there is a decrease in metamorphism which appears to be only temporary, for the rocks resume their schistose condition around Lansdowne and near the granite of this area become garnetiferous. While in Tehri Garhwal and Dehra Dun, the Nagthat beds form part of the Krol *nappé*, in British

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[1] *Rec.*, LXXI, Pl. 37, sect. 1 (1936).

[2] *Rec.*, 72, 84 (1937).

Garhwal they share in the formation of the Garhwal *nappé*. Low down in the Medi Gad Section, however, not far from Lansdowne, are ripple-marked quartzites exactly like those in the Jaunsars of Simla and Chakrata. The Nagthat series forms part—probably the lowest part—of Middlemiss, "Purple Slate series", identified first in Tehri Garhwal and British Garhwal and afterwards in the district of Naini Tal, forming the whole of the northeastern and part of the southwestern rim of the basin which encloses the lake and town of that name.[1] Some of the Nagthat and Chandpur beds were included by Middlemiss in his "Inner Schistose series" of the same region. The so-called "Purple Slate series" and "Volcanic Breccia" were found by Auden to be a mixture of Infra-Krol, Blaini, Nagthat and Chandpur beds.

Auden draws attention to the similarity between the Nagthat beds and the Tanawals of Kashmir, which are described below; both are continental formations, both show variation in the degree of metamorphism, and both present anomalous relationships to surrounding formations.

TANAWAL (TANOL) SERIES.

Hazara.—Bordering part of the Slate zone of Hazara, along its inner or northwestern boundary, is an irregularly lenticular patch of metamorphosed sediments consisting of two members, the exact interrelationship of which is uncertain. The calcareous member, the "Infra-Trias" of Middlemiss, is described by Wynne as lying in synclinal folds of the quartzose member, and will be dealt with under the heading of Carboniferous. At the same time, the possibility of the quartzose being, to some extent at least, but a silicified modification of the calcareous member must not be overlooked. The quartzose member is, broadly speaking, the "Tanol series" of Wynne, called after the ancient name of the country in which they are found in northwest India. A belt of these strongly quartzose, slightly schistose sediments has been recognised further to the northeast, lying in the Dogra Slates of eastern Mansehra and extending up into the Kaghan valley.[2]

The outcrops of the Tanawal series—to adopt the more modern spelling—are in most cases confluent with those of the Infra-Trias, from which it seems probable that there is no break of any magnitude between the two groups.[3] The difficulty regarding their mutual relationship is lessened if it be assumed that there are two distinct conglomerates, one at the base of the Tanawals and the other at the base of the younger Infra-Trias. As we have seen, there is good reason to believe that two such conglomeratic horizons are present in the Simla and Chakrata areas, one the well-known Blaini, and the other and older forming part of the Jaunsar or Nagthat series. The conglomerate beds of the Tanawals might thus be members of the Jaunsar or Nagthat sequence; the Tanakki Conglomerate, overlying the Tanawals and forming the base of the Infra-Trias would, under this scheme, correspond to the Blaini of Simla.[4] That the Tanawals may be the equivalents of the Jaunsars receives support from the opinion of Middlemiss who remarks that "in Jaunsar the 'Bawar' quartzites seem unmistakably

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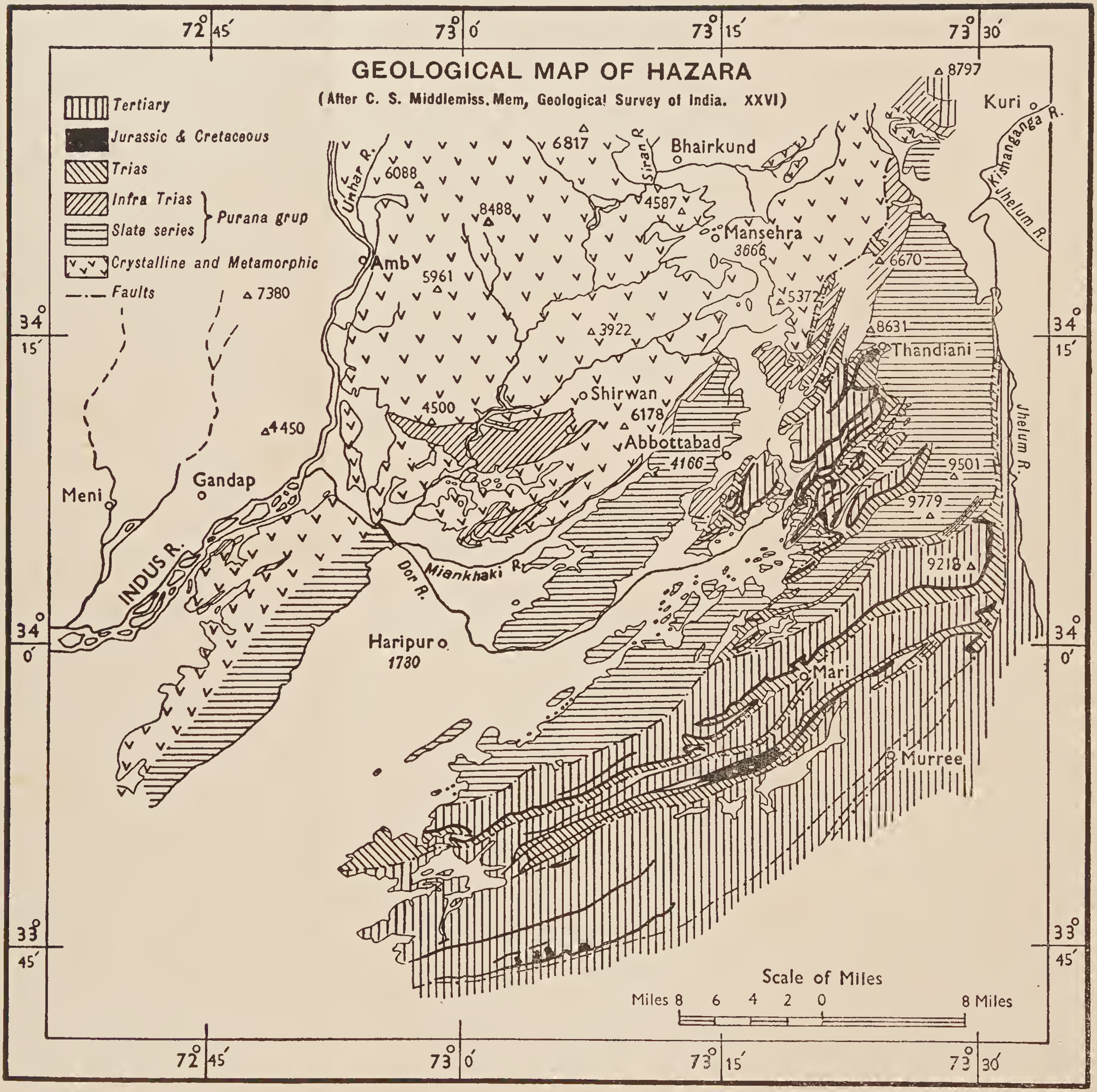
[1] *Rec.*, XX, 34 (1887); *Ibid.* XXIII, 218 (1890); *Ibid.* LXVI, 461 (1932).

[2] The provisional "Jured series" of Wadia. *Rec.*, LXIII, 131 (1930).

[3] C. S. Middlemiss. *Mem.*, XXVI, 238 (1896).

[4] J. B. Auden. *Rec.*, LXVII, 421 (1933).



GEOLOGICAL MAP OF HAZARA

(After C. S. Middlemiss. Mem, Geological Survey of India. XXVI)

Tertiary
Jurassic & Cretaceous
Trias
Infra Trias
Slate series
Purana grup
Crystalline and Metamorphic
Faults
72° 45′
73° 0′
73° 15′
73° 30′
34° 15′
34° 0′
33° 45′
8797
Kuri
Kishanganga R.
Jhelum R.
6817
Siran R.
Bhairkund
Unhar R.
6088
4587
8488
Mansehra
3666
Amb
5961
6670
7380
5372
3922
8631
Thandiani
Shirwan
6178
4500
4450
Abbottabad
4166
9501
Gandap
Meni
9779
INDUS R.
Dor R.
Miankhaki R.
9218
Haripur
1730
Mari
Murree
Scale of Miles
Miles 8 6 4 2 0 8 Miles

G. S. I., Calcutta.

to be the equivalents of the Tanols ".[1] Wadia and West also note that among the Tanawals there occur rocks lithologically very similar to the massive pebbly quartzites of the Jaunsar series.[2] In places Tanawals attain much the same grade of metamorphism as the Dogra Slates with which they are so frequently infolded, and there is sometimes a difficulty in drawing a boundary between the two, though the Tanawals are probably much the younger. The high grade of dynamic metamorphism seen in some members of the Tanawal series in the northeastern parts of the district—for example, in the thinly foliated quartz-schists and mica schists—was regarded as indicating an age older than that of the Gondwana; although such a criterion is unreliable in a much folded area, the apparently conformable passage of these sediments into the Agglomeratic Slate at Jured favours an age a little older than that of the Panjal Volcanics, of which the Agglomeratic Slate forms a part. This would make the Tanawals probably Devonian, partially equivalent to the Muth Quartzite, perhaps extending up into the lower part of the Carboniferous.[3]

The Tanawal Conglomerate, or Talhatta Conglomerate as it has been called, is more deformed than the supposedly younger Tanakki Conglomerate, though both are found in the same metamorphic belt. In the more advanced stages of deformation, the pebbles of the Tanawal Conglomerate are drawn out and flattened into mere flakes; these are traversed by parallel shear planes along which metamorphism has commenced and whose boundaries have been obscured.[4]

The northern boundary of the Tanawals is vague and indefinite, but according to Middlemiss, shearing and reversed faulting have been the main agents in bringing about the apparent merging of the Tanawals into the more ancient crystalline schists which succeed them in this direction.

The Tanawal series, well exposed in the Gandgarh range on the Indus in western Hazara, comprises a well-stratified sequence, according to Wadia, of purple, grey and white quartzites (metamorphosed sandstones) with quartz schists and phyllites, associated with some massive quartzitic beds having peculiarly scoured and grooved surfaces and containing veins, layers and patches of coarsely crystalline dolomite.[5] Wynne describes it as consisting of quartzose rocks, some of them almost unchanged sandstones, in rapid alternation with dark, earthy bands, flaggy, shaly or slightly schistose, with occasional conglomeratic slates containing pebbles of quartz and quartzite ranging up to the size of a goose's egg.[6] Middlemiss speaks of the series as varying little in character. According to him, the basal conglomerate is succeeded by extremely fissile purple slates whose surfaces are minutely speckled. The latter are followed by limestones, and quartz schists or quartzites, which appear to alternate with one another. The quartz schists and schistose quartzites, of which a very great thickness is exposed in Tanawal and the Gandgarh range, are white or cream in colour, massive, rather coarse, felspathic, and faintly conglomeratic in places. The Tanawal outcrops in Hazara are always contiguous to outcrops of Infra-Trias limestone.

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[1] *Mem.*, XXVI, 239 (1896).

[2] Gen. Rep. *Rec.*, LXV, 127 (1931).

[3] Gen.Rep. *Rec.*, LXIII, 132 (1930) ; a recent suggestion is that the Upper Tanawals belong to the basal Gondwana sequence (D. N. Wadia. *Rec.* 72, 75 (1937)). This would mean a partial correlation with the Blaini and probably the equivalence of the Tanawal and Blaini Conglomerates it would also place the Tanawal formation within the Carboniferous.

[4] C. S. Middlemiss. *Mem.*, XXVI, 55 (1896).

[5] *Rec.*, LXVI, 121 (1932).

[6] *Rec.*, XII, 122 (1879).

A minimum thickness of 20,000 feet has been suggested for the Tanawals by Wynne, but to what extent this is exaggerated by repetition is not known. The dip of the foliation and shear planes is low and invariably inwards towards the higher mountains.

Of the quartzites and quartz schists great thicknesses are exposed in Tanawal and the Gandgarh range. In spite of the dynamic metamorphism which has so manifestly affected them, in common with many other rocks of this region, they have not the appearance that generally appertains to quartzites of very great antiquity; the separate grains of the rock are loosely aggregated together, uncemented by secondary silica, and the rock itself is far from being a glassy quartzite. The fresh quartzo-felspathic material and the coarseness of the grain indicate a granitic source, while the slight metamorphism of the rocks is attributed by Middlemiss to the intrusion of the basic trap dykes which are found seaming the Tanawals, Infra-Trias and Dogra Slates, but none of the younger rocks of Hazara. Many of these somewhat remarkable quartzitic rocks show lenticular-tabular foliation to an advanced degree. Wherever a coarse grain of quartz occurs in the rock, it has been powdered and drawn out into an eye, and where-ever pebbles occur the same distortion has happened to them or they appear to have suffered a slipping of one part over the other.

The Himalaya-Hazara syntaxis.—The Tanawals have been recognised by Wadia in the syntaxis at the western end of the Himalaya, and the series continues interruptedly from Hazara around the syntaxis into Kashmir. In the western part of the syntaxis, the stage of the Tanawals next to the Dogra Slates, and therefore probably the base, is a conglomerate, 200 feet thick, with a slaty matrix. The pebbles are of white and pink quartz, crowded in some place, scattered in others, a few of them sub-angular or drawn out into *augen*; the matrix is not unlike a glacial tillite. Throughout the northward extension of the Tanawals into Kaghan and thence eastwards and southwards in discontinuous belt into the Karnah district of Punch, the basal conglomerate has not been observed.[1]

The rest of the series in this area, according to Wadia, is composed of quartzites, quartzose sandstones and conglomeratic phyllites. The quartzites may be pebbly and gritty, or slabby and partly schistose, while the phyllites are mostly sandy and seamed with beds of pebbles, some of them well rounded. It is possible that some of the conglomeratic layers are of autoclastic origin.

It is their markedly sandy and quartzose composition which distinguishes the Tanawals from the monotonous Dogra Slates. The beds tentatively mapped in this region as Tanawals may include some younger as well as some older horizons. Possibly some of the coarsely crystalline quartzites are in reality silicified forms of the Infra-Trias (? Carboniferous) limestones. Wadia, in fact, suggests that much of the 2,000 feet of the limestone of the *Infra*-Trias has—for instance, in Mansehra and the adjacent parts of the Muzaffarabad area—been silicified by a process of metasomatic replacement into massive coarse-grained quartzites or grits; even the uppermost portion of the limestone is thought to have been so affected. If and to what extent the Tanawals and Infra-Trias overlap will be better understood after further investigations have been carried out.[2] We must also be prepared to find that the more massive finer-grained varieties of the quartzites allotted to the Tanawals of the arenaceous beds represent the Muth Quartzite, with a stratigraphical position perhaps below the basal Tanawal conglomerate.

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[1] *Rec.*, LXV, 204, (1931).

[2] *Rec.*, LXVIII 147-148 (1934).

In the Himalaya-Hazara syntaxis the Tanawal rocks are in many places extensively invaded by intrusions of granite which has sometimes permeated the sediments in *lit-par-lit* fashion, producing types resembling the Finnish migmatites.

Southwest Kashmir.—In southwest Kashmir, a great thickness of these highly arenaceous schistose rocks is again exposed, comprising metamorphosed, prominently banded, argillaceous sandstones, arenaceous phyllites, quartz schists, massive quartzites, at times felspathic, and grits, with autoclastic as well as true clastic conglomerates. The crushing and distortion experienced by the Tanawal beds add to the difficulty of their correlation. The group is totally barren of fossils and here again, as in the syntaxis further northwest, has probably been made to include horizons above—and perhaps also below—the limits of the series as defined by Wynne and Middlemiss.

To the north of Punch State and a few miles west, southwest and south of the town, of Handwara (Hundawor), an interrupted belt, consisting of three ill-defined basins of the Tanawal series, has been mapped by Wadia. All three basins have been involved in the corrugations of the Dogra Slates. The greater part of the boundary of these outcrops is made with either the Salkhala series or the Dogra Slates ; occasionally it is in contact with intrusive granite. The most southerly and largest of the three main tracts is partly delimited by the Panjal Trap.

This large outcrop, which lies to the south of Handwara in the districts of Uri and Baramula, comprises a great thickness of moderately metamorphosed shales, azgillaceous sandstones, and quartzites, situated on the southwest side of the Pir Panjal and mapped at first as doubtful Lower Gondwanas. These beds overlie the Dogra Slates with a violent unconformity which is usually marked by an extremely coarse boulder conglomerate, about 250 feet in thickness, at the base of the younger series. Since the rocks have here been affected by two or three inversions or recumbent folds with a persistent dip to the N. E. or E. N. E., the basal conglomerate is not always found in its normal position at all points of the meandering strike. Along what is presumed to be their upper boundary, the Tanawals, which must be several thousand feet in thickness, come into apparently normal and conformable contact with the Agglomeratic Slate with its Gondwana flora of *Gangamopteris*, *Alethopteris*, *Cordaites* and other plants. In some places, in fact, especially on the ridge connecting Apharwat with Pathri (13,938 feet), a peak composed of Tanawal rocks, the Tanawals seem to pass up more or less gradually into the Agglomeratic Slate.[1] In the Chor Panjal Pass also, a few miles further south, there is a conformable passage up into the Agglomeratic Slate of unfossiliferous arenaceous beds which, it is supposed, belong to the upper Tanawals.[2] If this be correct, it may be that the lower limit of the Agglomeratic

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[1] Coulson. *Rec.* 73, 88 (1938). They were at first thought to overlie the Agglomeratic Slate (*Mem.* LI, 244 (1928) : *Rec.* LXII, 153 (1929)). *Rec.*, LXVIII, 147-148(1934).

[2] *Rec.*, 42,73 (1937).

Slate—a formation known to vary widely in stratigraphical level from place to place—is here at some horizon below the Talchir (Upper Carboniferous) Boulder Bed which is absent from this section ; the alternative is that the Tanawals are younger than at first supposed, *i.e.*, Carboniferous (Middle or Lower *plus* Middle) instead of Devonian. The agglomerate is here a coarse rock in which are fragments of Tanawal rocks, presumably blown out by an explosive outburst heralding the outpouring of the Panjal Trap. Traversing the ill-defined boundary line between this Tanawal outcrop and the Dogra Slate near Buniyar is a plug of gabbro surrounded by doleritic masses, belonging probably to the Panjal Trap.[1] Southeastwards, a broad tract of the Tanawals, which, as in Hazara, are remarkably uniform in character and composition, extends approximately parallel to the Dogra Slate and Salkhala belts into Punch, tightly pressed against the Panjal Volcanics from Apharwat near Gulmarg to just south of the Pir Panjal Pass where its disappearance is the result of an abrupt rise of the fold axes. Four or five miles to the east of the Pass, however, another narrow outcrop of the Tanawals commences within the Panjal Trap and stretches southeastwards.

Wadia gives the following order of superposition with the thicknesses :

4. Massive and flaggy, current-bedded, ripple-marked quartzite, white or brown in colour.	Thickness variable but having a maximum of 5,000 feet.
3. Buff and grey, argillaceous sandstone, showing colour-banding, universal current-bedding, and incipient cleavage.	
2. Black (carbonaceous), grey or green, arenaceous shales and phyllites.	
1. Boulder conglomerate	0-150 feet.

The conglomerate, though very inconstant and lenticular, is widely prevalent and is composed of a fine-grained slaty or phyllitic matrix in which are embedded moderately rounded boulders of the size of cokernuts, consisting exclusively of white quartz ; in none of these boulders have any clear traces of ice grooving, facetting or polishing been found. The conglomerate passes up gradually into the arenaceous phyllites and slates by the decrease in the number and size of the pebbles and the increase in the volume of the slaty matrix. Ferruginous impressions on the laminae of shales and argillaceous sandstones, widely scattered at some localities but absent at others, suggest the former presence of leaves and stems, while a sigmoidal structure resembling a vertebrate skeleton has been recorded in one place ; this evidence is thought to indicate a terrestrial and fluviatile origin for the sediments in which they occur. Thinning-out and overlap of one stage by the next are constant features of the succession.

Northwest of Gulmarg, the belt of Tanawals extends as far as the Jhelum gorge, where the strike becomes more westerly, and for a few miles beyond. A number of more or less parallel, severed, synclinal outliers of these rocks are also to be seen amid deep corrugations of the Dogra Slates.

(For a brief sketch of the palæogeography of the Devonian, see the end or the following chapter.)

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[1] *Rec.*, LXV, 124-125 (1931).

CHAPTER XIX.

DEVONIAN-CARBONIFEROUS-PERMIAN SEQUENCE, AND DOUBTFUL EQUIVALENTS IN BURMA.

I.—The Plateau Limestone : Position and extent; Organic remains; Physiography: superficial ore deposits; Deposition round islands; Sub-division; Thickness. **A. Dolomitic Type of the Plateau Limestone : (i) Northern Shan States.** —Character, mineralisation; Padaukpin fauna; Wetwin fauna; *Phillipsastraea* assemblage; other fossils; Conditions of deposition; (ii) **Myitkyina :** (iii) **Yunnan :** (iv) **Kyaukse district :** (v) **Meiktila, Yamethin and the Southern Shan States :** Physiography; Paunglaung range; Hsa-Mong-Hkam band; Lawksawk; Taung-gyi Htam-sang tract; Wanpong-Melawn belt; Other extensions; Comparison with the Northern Shan States; A younger dolomitic division. **B. Calcitic Type of the Plateau Limestone :** Limited extent; (i) **The Northern Shan States :** Mode of occurrence; Origin; Relations to the succeeding Namyau beds; The Namun fauna; Fossil localities; (ii) **Myitkyina district :** (iii) **Southern Shan States :** Kehsi Mansam fauna; Country between Taung-gyi and Mong Pawn; The Htam Sang locality; Other localities; **Relationships of the faunas.** Karenni States. Yunnan. Indo-China. **II.—Moulmein Limestone : Thaton and Amherst districts. Salween district : Tavoy district : Mergui district : Relationships of this Moulmein Limestone. III. Mergui Series :** Stratigraphical position; **Tavoy :** Physiography: Lithology and structure; Argillaceous members; Pyroclastic deposits; Arenaceous beds; Limestones; **Mergui :** Physiography; Structure; Lithological character; Argillaceous types; Conglomerates; Arenaceous beds; Limestones; Pyroclastic rocks; Schistose types, pegmatites and quartz viens. **Amherst :** Physiography: Lithological character; Contact with the granite. **Thaton. Karenni. Devonian Palaeogeography.**

The Zebingyi beds of the Northern Shan States have been described under the heading of Silurian, in view of the specimens of *Monograptus* they contain. Nevertheless, various elements of their fauna, such as *Phacops* (*Dalmanites*) *swinhoei* Reed and *Tentaculites elegans* Barr.—the latter occurring throughout the inconsiderable thickness of the group—are of Devonian aspect, and there is much to suggest the top of the Lower or even the base of the Middle Devonian. In faunal character, if not in chronological and stratigraphical position, the Zebingyi stage has every appearance of straddling the Upper Silurian and Lower Devonian.

1. THE PLATEAU LIMESTONE.

Position and extent.—The greater part of the Northern Shan States of Burma is occupied by a vast plateau which derives its distinctive plateau-like character from the peculiar constitution and mode of weathering of the most widely prevailing rock, the Plateau Limestone. From the Yunnanese border in North Hsenwi, about latitude 24°N., it extends southwards, spreading at the same time westwards; farther south it narrows and terminates more or less at latitude 20° 20′, on the borders of Möng Nai and Mawk-Mai States.[1] The western edge of the plateau, facing the Irrawaddy valley is usually a precipitous scarp, evidently the result of long-continued sub-aerial denudation. Along the line dividing the plateau from the hilly country of the

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[1] J. Coggin Brown. *Rec.*, LVI, 86 (1924).

Tawng Peng State is a similar scarp separated from the more rugged country beyond by a more or less broad valley, on the floor of which the rocks of the subjacent series are exposed, but no outliers of this limestone are to be found on the older rocks of Tawng Peng.[1] Portions of the main plateau about the western edge have been let down by a series of step faults, trending N.-S., of comparatively recent date. Elsewhere, in both the Northern and Southern Shan States, the plateau-like topography is characteristically disturbed by block and subsidence faulting, mainly in a N.-S. direction, with the production of great scarps extending in comparatively straight lines for many miles. The limestone wall dominated by Taung-gyi, the capital of the Federated Shan States, and forming the eastern side of the Yawnghwe valley, is probably an example of such a fault scarp.[2] Along certain lines the faulting is thrust-like, and younger beds are seen isoclinally folded into the Plateau Limestone.

To the north, the Shan plateau is bounded by the exceedingly broken hilly region occupied by the Silurian, Ordovician and pre-Cambrian Chaung Magyi rocks which, further in this direction, give place to the gneisses and crystalline limestones of Mogok and adjacent areas. The Northern Shan States area is drained by the Nam Tu and its feeders, which often flow in narrow, profound gorges through the limestones. Practically the whole of the plateau is occupied by these dolomites and limestones which, in a few localities, have yielded fossils varying in age from Devonian to Upper Permian. The bulk of the country rock, however, is concealed by a thick mantle of red clay.

On the west, opposite Mandalay, the limestones come down for a short distance to the edge of the Irrawaddy alluvium, but north and south of this tract they are separated from the plains by a strip of crystalline rocks; this limestone belt here has a maximum width of eight miles.[3] Southwards, the limestones extend through Kyaukse and the Southern Shan States, Karenni and Siam, and are in part represented by the Moulmein Limestone of Tenasserim, which is exposed at Moulmein and at isolated localities further south.[4] Northeast of the Shan States, limestones similar to the Plateau Limestone have been found in Yunnan, and rocks of the same age occur over a wide area in other parts of China. Eastwards, these limestones extend across the Salween and Mekong. How much of them has been removed by denudation and to what extent they exceeded their present limits, both horizontally and vertically, it would be difficult to say.

Traced eastwards into South Hsenwi, the Plateau Limestone, after an interruption in the form of a band composed of Namhsim sandstones (Silurian), Hwe-Mawng beds (Ordovician) and Naungkangyis (Ordovician), occupies the Loi se hill range overlooking the Salween. The gorge of the latter river, nearly 5,000 feet deep, is walled on the west by an enormous well-defined scarp of the limestone. On the other side of the river, lying mostly upon rocks belonging apparently to the Chaung Magyi series, outcrops of the limestone which have been noted by Sondhi around Pang-hsang above the Nam Hka, compose the peaks of Pola She and Hko Di Shan; east of the latter is an inlier of the Chaung Magyi rocks, beyond which the Plateau Limestone is again seen.[1] The Plateau Limestones are not as a rule thrown into steep folds, except among the eastern ranges—a result probably of their immense thickness. The effect of earth movement seems to have been limited to brecciation and to the production of violent contortion in occasional bands of the rock. The angle of dip seldom exceeds 30° and the beds are often horizontal.

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[1] T. H. D. La Touche. *Mem.*, XXXIX, Pt. 2, 184 (1913).

[2] J. Coggin Brown. *Rec.*, LXV, 415-416 (1931).

[3] Gen. Rep. *Rec.*, LXIX, 54 (1935).

[4] Fritz Noetling. *Rec.*, XXVI, 96 (1893); *Sel. Rec. Gov. Ind.*, X, 33 (1856); W. Theobald. *Mem.*, X, Pt. 2, p. 138 (1873).

Organic remains.—The almost universal recrystallisation of the greater part of the limestone as dolomite has destroyed original structures to such an extent that it is exceedingly rare to find any trace of organic remains, except in the purer and what has been regarded as the upper part of the formation. Occasionally traces of crinoid ossicles, coral septa or thecae, or minute foraminifera can be made out. In some of the oolitic dolomites, for instance, lying in the groundmass outside the oolitic grains numerous specimens of minute foraminifera have been observed ; among them a species of *Endothyra* is most common, with a few *Textularia*. The organic origin of the limestone has never been questioned but, with a few noteworthy exceptions, which merit the most detailed attention scarcely a single determinable fossil visible to the naked eye has been found throughout the continuous expanse of the limestone extending from Maymyo to the Salween.

Physiography.—The scenery of the Plateau Limestone country consists of a monotonous succession of wide shallow valleys separated by low swelling hills or ridges, their outlines smoothed off by the universal covering of clay, except where one of the numerous cañonlike gorges occurs, or in a few places where a scarp, usually indicating a line of fault, presents to the view a succession of precipitous cliffs.[2] For the most part, it is a country of gentle declivities, covered after the rainy season with a dense matting of elephant grass, interspersed in places with low scrub jungle and in others with park-like savannahs of scattered oak trees. The soil is of poor quality and vegetation is limited. The narrow V-shaped gorges, however, are frequently buried in dense jungle or sometimes clothed with pine forests. The common bracken fern (*Pteridium aqulinum*) is typical of the Plateau Limestone and is universal over the limestone area. A striking feature in the scenery of the Shan plateau is the enormous number of cup-shaped depressions, varying in width from mere sink-holes of a few yards diameter to broad valleys several miles in length ; the smaller of these excavations are especially common along the crests of fault scarps or near the edges of the deep cañons in which the larger rivers flow.

Superficial ore deposits.—The red clay, which forms so thick a blanket covering the limestone, sometimes contains important deposits of residual iron ores. The hæmatitic ores of Kung-hka, occurring in a fault in the Pangyun beds, are thought to have been derived from the Plateau Limestone which originally covered the older series[3] ; the Manmaklang deposit near Man Pwe, consisting mostly of limonite, occurs on the surface of the Plateau Limestone.

Deposition round islands.—The general trend of the ridges is N.W.-S.E. in the north but becomes more meridional towards the south. The majority of these ridges are from 4,000 to 5,000 feet above sea-level, rising locally to peaks of 6,000 and 7,000 feet. Masses of older rocks, like those of Loi-ling (8,842 feet) and the Loi-pan Loi-twang range, rise from the plateau like mountainous islands from an encircling sea. As Mr. La Touche remarks, it seems probable that at the time the limestones were being accumulated, the Shan sea was studded with islands occupying the same topographical position as the present ranges, though not of the same dimensions and altitude—a suggestion supported by the sandy nature assumed by the limestone as the base of these island-like masses is pproached, and by abundant evidence of the overlap of the lower beds of the limestone series by the higher. The older Palœozoic rocks, seen along the fringes of the plateau, are also exposed in the deep gorges where the covering of dolomite has been eroded through, or in the hill folds where it has been planed away. The evidence of disturbance at the end of Namhsim (Silurian) times is conflicting, but the Plateau Limestone overlaps all the underlying formations[1].

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[1] Gen. Rep. *Rec.*, 73, 71 (1938).

[2] T. H. D. La Touche. *Mem.*, XXXIX, Pt. 2, 182 (1913).

[3] Gen. Rep. *Rec.*, LV., 20-21 (1923).

Sub-division.—Although deposition extended from the close of the Silurian period—as shown by the graptolites of the Zebingyi beds—to the Productus and Fusulina limestones of Permian age, the task of sub-division is rendered almost hopeless by the paucity of organic remains, the rarity of exposures, the homogeneity of the formation, and irregularity of the dislocations which have affected the rocks. It is unlikely that marine deposition throughout the period represented by the Plateau Limestone was continuous, extending from the Devonian to the upper Permian, but to what extent the Shan States shared in the various invasions and regressions of the sea which took place over adjoining areas in China and Indo-China during this long period, is not at present definitely known.

The calcitic or so-called " upper " limestones, although of a different texture and composition from the microcrystalline dolomites beneath, are in the Northern Shan States so feebly developed and their relationship to the underlying rocks so extensively concealed, that it is usually impossible to determine where the one ends and the other begins, or even whether they are conformable to one another or not. In the Southern Shan States, the calcitic limestones are better developed, and more easily separable, but here, there is some reason for supposing that they are succeeded by further thicknesses of the dolomitic, brecciated variety. It would seem advisable, therefore, to avoid the terms " Lower " and " Upper " and substitute for the former " the dolomitic type " and for the latter " the calcitic type ". To summarise, therefore, we find in the Southern Shan States some of the dolomitic type occurring apparently above as well as below the calcitic variety, and it is not impossible that a similar sequence may exist in the Northern Shan States, though the bulk of the dolomitic type is probably older than the other.

Thickness.—The total thickness of the Plateau Limestone formation is not easily estimated. In the gorge of the Nam Tu, about fifteen miles south of Maymyo, not less than 2,500 feet are exposed, but there is no determinable upper limit. At least 2,000 feet are visible in the Gokteik gorge, but in this case the base is not observable. There is a more complete section on the left bank of the Nam Tu, to the north of Hsipaw, where the base and top of the group are well defined, showing a total of 6,600 feet, but even in this case some portion may have been removed before the deposition of the overlying Namyau series (Jurassic), since banks of calcareous conglomerate filled with well-rolled pebbles of the limestone have been noted in several places at or near the base of the Namyau beds, proving that some denudation had taken place in the interval. The band exposed on the northern flanks of the Loi-len range, where the red beds of the Namyaus are also in position above it, is fairly uniform in width towards the western end of the range and shows a thickness of 5,500 feet or more.

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[1] *Mem.*, XXXIX, Pt. 2, 351 (1913).

A. DOLOMITIC TYPE OF THE PLATEAU LIMESTONE.

(i) NORTHERN SHAN STATES.

Character.—The prevailing type of rock in the formation under consideration is a whitish or light grey dolomitic limestone, weathering to a darker grey, often stained red by iron oxide both on the surface and along joint-planes. It is often hard enough to produce a spark when struck with a hammer; when so struck, it usually gives out a more or less fœtid odour, thought to be due to the presence of decomposed organic matter. It has a finely granular appearance and, except near its boundary with older formations, where it occasionally passes into a sandy limestone or even a calcareous sandstone, the proportion of contained silica or argillaceous matter is extremely small. In spite of this, the rock has a deceptive sandy touch. Analyses of Plateau limestones show that there is every variety from a pure limestone of over 99 per cent. of calcium carbonate to a practically true dolomite with 55 per cent. of calcium carbonate and 44 per cent. of magnesium carbonate; the pure varieties, however, belong to the Permian horizon and will be considered later on. All those limestones which form the massive non-fossiliferous bulk of the formation contain an appreciable amount of carbonate of magnesia. Under the microscope, they are seen to consist of an aggregate of minute dolomite grains of irregular outline, interlocking with one another. Excluding the obviously impure sandy forms, the specific gravity of these dolomitic rocks varies between 2·72 and 2·85. Some of the limestones are oolitic.

The series includes occasional bands of limestone breccia re-cemented *in situ*, formed apparently while the limestone was being deposited and probably of the nature of "reef-talus". Apart from these bands, however, there is a general brecciation of the formation as a whole, which is one of the most characteristic and universal features thereof. La Touche remarks that it is difficult to find a piece of the limestone large enough for a hand specimen which is not traversed in all directions by a network of secondary calcite or dolomite veins. The fact that such veins are often seen to be faulted across by others proves that the crushing movement was prolonged and interrupted. Sometimes the filling of the veins has been leached out, in which case the rock can usually be pulverised by a single blow into a heap of scree or ballast. Slickensided surfaces are not uncommon. The major cause of such brecciation is seen in the great earth movements which took place at the close of Mesozoic era, the effect of which is also evident in the overlying Napeng and Lio-an stages.

Silver lead ore is found in places among the limestones of the Shan Pateau; this mineralisation is described in the sequel. The iron ore in the residual clay which caps the Plateau Limestone is also dealt with in a later Chapter.

Padaukpin fauna.—One of the outstanding exceptions to the almost universal barrenness of the lower part of this enormous mass of limestone occurs at the village of Pàdaukpin, about eleven miles E. N. E. of Maymyo. The fossils, which form a rich and varied assemblage of Middle Devonian age, have long been known to the Burmans and used by them as charms. The number of individual specimens, some of them in perfect preservation, is extraordinary, *Cyrtina heteroclita*, for instance, being washed out of the bed in hundreds. A close search has failed to find this particular bed anywhere else in the neighbourhood. The following forms have been identified by Dr. Cowper Reed[1]:

Actinozoa—
* *Cyathophyllum ceratites* Goldf.,
* ,, ,, ,, var. *marginatum* Goldf.,
* ,, *bathycalyx* Frech,
,, (*Phacellophyllum*) *cæspitosum* Goldf., var. *breviseptatum* Frech (Species found in Chitral),
,, *helianthoides* Goldf., var. *spinulosum* Reed,
* ,, (*Heliophyllum*) *cylindricum* (Schulz) (found also in Chitral),
,, *birmanicum* Reed,
,, cf. *quadrigeminum* Goldf.,
Blothrophyllum ? sp.
* *Endophyllum acanthicum* Frech ? (possibly identical with *Spongophyllum Wenjukowi* v. Peetz., from the Calceola Beds of Kusnetzk),
Diphyphyllum symmetricum Frech,
Zaphrentis aff. *cornicula* Lesueur,
Amplexus hercynicus Roem.,
* *Hallia callosa* (Ludw.)? (ill-preserved and not numerous),
,, *quadripartita* Frech,
* ,, *striata* Schlüt.?
* *Aulacophyllum looghiense* Schlüt.,
* *Cystiphyllum cristatum* Frech,
* ,, *vesiculosum* Goldf.,
* ,, *cæspitosum* Schlüt.,
* *Microplasma fractum* Schlüt.,
* *Calceola sandalina* Lam.,
* *Favosites goldfussi* d'Orb., var. *major* Frech,
* *Pachypora reticulata*, (de Blainv.),
* ,, *polymorpha* Goldf. e. p. (a variety found in Chitral),
* *Alveolites suborbicularis* Lam. (a variety found in Chitral),
* ,, (?) *clathrata* (Stein.)?
* ,, *ramosa* Roem. (found also in Chitral),
,, *subpalmata* Reed,
,, *illusa* Reed,
,, aff. *expatiata* (Rominger),
* *Cœnites escharoides* (Stein),
,, *expansa* Frech,
Striatopora cf. *angulosa* Gurich,
* ,, (?) *vermicularis* (McCoy),
Rhaphidopora crinalis Schlüt., var. *aculeata* Nich, & Foord,
* *Aulopora serpens* Goldf.,
,, cf. *tenuis* Münster,
,, *subcampanulata* Reed,
Cladochonus aff. *schluteri* Holz.,
* *Aulocystis cornigera* Schlut.,
Heliolites interstinctus (Linne).

Hydrozoa—

Stromatoporella curiosa (Barg.)?
* ,, *eifeliensis* Nich.?
,, cf. *granulata* Nich.,
Actinostroma clathratum Nich., var.

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[1] *Pal. Ind.*, New Ser., Vol. II, Mem. 5 (1908).

Crinoidea—
Storthingocrinus fritillus (Wirtg. & Zeil.),
Cupressocrinus schlotheimi (Stein.)?
,, cf. _crassus_ Goldf.,
Bactrocrinus birmanicus Reed,
Hexacrinus aff. _pyriformis_ Schultze,
,, aff. _elongatus_ Goldf.,
,, cf. _spinosus_ Goldf.,
Lecythocrinus sp.

Chætopoda—
* _Spirorbis omphalodes_ (Goldf.),
Ortonia cf. _devonica_ (Pacht.)

Bryozoa—
Fistulipora quærenda Reed,
,, _tempestiva_ Reed,
,, _cunctata_ Reed,
,, _memor_ Reed,
,, cf. _vesiculata_ (Hall),
,, aff. _favosa_ Goldf.,
,, (_Fistuliporella_ ?) _deterrens_ Reed,
Eridopora multidecorata Reed,
Selenopora cœlebs Reed,
Buskopora semilunata Reed,
Hederella cf. _magna_ Hall,
Fenestella arthritica Phill.,
,, aff. _polyporata_ Phill,.
Fenestrapora isolata Reed,
Hemitrypa oculata Phill.,
,, _inversa_ Reed,
Unitrypa sp.,
Polypora populata Whidb.,
,, _birmanica_ Reed,
,, _ultimata_ Reed,
Ptilopora sp.,
Streblotrypa sp.

Brachiopoda—
Stropheodonta interstrialis Phill., var. _birmanica_ Reed,
,, _subtetragona_ Roem., var. _padaukpinensis_ Reed,
* ,, (_Leptostrophia_) _palma_ Kayser,
* _Strophonella caudata_, (Schnur),
Leptæna rhomboidalis Wilck.,
* _Orthothetes_ (_Schellwienella_) _umbraculum_ (Schloth.),
* _Kayserella lepida_ Schnur. ?
* _Chonetes minuta_ (Goldf.),
* ,, _sarcinulata_ (Schloth.),
* _Orthis_ (_Schizophoria_) _striatula_, (Schloth.),
* ,, (_Rhipidomella_) _eifeliensis_ de Vern.,
Scenidium areola (Quenst.),
*_Pentamerus_ (_Gypidula_) _brevirostris_ Phill.,
* ,, ,, _biplicatus_ (Schnur).
Camarophoria lummatoniensis Dav.,
,, cf. _brachyptycta_ (Schnur),
* ,, cf. _ascendens_ (Stein.),
* _Wilsonia cuboides_ Sowerby, var.,
Hypothyris lungtungpeensis Kayser ?
,, _pentagona_ (Goldf.),
,, _scknuri_ (de Vern.),
,, ,, , var. _transversa_ Reed,
Camarotœchia, _subsignata_ Reed,
* _Atrypa reticularis_ (Linne),
* ,, ,, , var. _desquamata_ Sow.?
,, _aspera_ Schloth., var. _sinensis_ Kayser,
Glassia whidbornei Dav.,

Spirifer padaukpinensis Reed,
,, ,, . var. *dagon* Reed,
* *Reticularia curvatus* (Schloth.),
* ,, *avicpes* Kayser,
* *Martinia inflatus* Schnur,
,, cf. *batschati* von Peetz,
* *Cyrtina heteroclita* (Defr.),
,, ,, , var. *multiplicata* Dav.,
* *Athyris concentrica* (von Buch),
* *Nucleospira lens* (Schnur),
* *Ptychospira longirostris* (Kays.) var.,
* *Merista* (*Dicamara*) *plebeia* (Sow.),
Meristella cf. *haskinsi* Hall,
,, ? *subdidyma* Reed,
,, ? *subservata* Reed,
,, aff. *lacryma* (Sow.),
,, cf. *upsilon* Barr.

Lamellibranchiata—
* *Conocardium rhenanum* Beush. var.,
,, aff. *eifeliense* Beush.,
* *Paracylcas proavia* (Goldf.),
* ,, *rugosa* (Goldf.),

Gastropoda—
* *Platyceras compressum* (Roem.),
,, *orientale* Reed,
Loxonema aff. *rugiferum* Phill.,
,, cf. *funatum* Roem.,
Pleurotomaria (*Euomphalopterus*) cf. *subalata* de Vern.,
Murchisonia sp.,
* *Euomphalus radiatus* Goldf., (*non* Phil.),
,, *wahlenbergi* Goldf.,
* *Bellerophon lineatus* Goldf.

Cephalopoda—
Orthoceras aff. *laterale* Phill.,
* *Anarcestes* cf. *lateseptatus* (Beyr.),
Agoniatites sp.

Trilobita—
* *Phacops latifrons* (Bronn) var.,
* ,, (*Dalmanites*) cf. *stellifer* Burm,
* ,, ,, *punctatus* Stein.

Of the above forms all those marked with an asterisk, about one-third of the whole, are found in the *Calceola*-stage, *i.e.*, the lower part of the Middle Devonian, of western Europe; all the characteristic fossils of this stage, such as *Calceola sandalina, Cyrtina heteroclita, Orthothetes umbraculum*, are specially abundant.[1] Although separated by 90° of longitude and 35° of latitude, this fauna is remarkably similar to that of the Eifel district of Germany not only in facies but in the calcareous nature and physical characters of the containing rock as well as the mode of preservation of the fossils. The Burmese assemblage, in fact, suggests physical and biological conditions similar to those that prevailed during the formation of the limestones of the Eifel district, where corals and brachiopods also predominate among the Devonian forms. Dr. Cowper Reed places it in the uppermost of the three zones of the *Calceola*-stage, *i.e.*, the zone of *Spirifer speciosus* and *Grünewaldtia latilinguis*; although neither of these zone fossils has been found, 14 of the Padaukpin forms are limited to, specially characteristic of, or appear first in, this zone. Givetian forms are not unrepresented, although the type fossil, *Stringocephalus burtini*, has not been found. Of the 26 new species or varieties from Padaukpin, none has any marked affinities with Upper Devonian forms. The American element is represented mainly by allied forms and resemblance is closest among the bryozoa, certain of the Padaukpin genera—such as *Selenopora* and *Buskopora*—not having been previously detected outside the American continent. The leading features in the assemblage collected from Padaukpin are : (i) the abundance, not only in number of genera and species but also in individuals, of corals, bryozoa and brachiopods ; and (ii) the extreme scarcity of most other groups, including the mollusca, the species of which are represented by extremely few individual specimens. La Touche has called attention to the fact that all those forms which are badly represented at Padaukpin—usually by casts—such as the mollusca, are those of which the original shell was composed partly or wholly of aragonite, and suggests that the predominating forms of life which produced the great bulk of the Plateau Limestone, were probably mollusca, and that the Padaukpin fauna, rich though it is, gives an incorrect picture of the life of the period in the Burmese region.[1] Remains of gastropods and bivalves are frequently seen in section on the face of the rocks and, though entirely converted into crystalline calcite, their outlines alone being left, they prove that these forms of life must have been much more abundant than a study of the Padaukpin collections would lead one to expect. It is impossible to say what horizon in the Plateau Limestone the Padaukpin reef occupies.

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[1] *Pal. Ind.*, New Ser., Vol. II, Mem. 5, 142 (1908).

Wetwin fauna.—The second exception to the general barrenness of the Plateau Limestone occurs at the base of a precipitous scrap, about a mile W. S. W. of Padaukpin, at the village of Wetwin, which is built upon a band of shale somewhat resembling a hard fissile " fullers' earth ", generally of a buff colour mottled with pink, grey or black stains. It has been traced to within half-a-mile of the *Calceola* beds of Padaukpin, but a shallow ravine crossing the line of strike prevents the inter-relationship from being observed. In the field, these beds appear as if they underlie the *Calceola* beds, but the intervention of a fault is not improbable, since the shales are described as faulted against the scrap, towards which they dip gently northwards ; in any case, the character of the fauna they contain points to a higher rather than to a lower position in the Plateau Limestone. The following is a list of specimens from these shales, determined by Cowper Reed :

Bryozoa—
  Fenestella polyporata Phill. var. *wetwinensis* Reed,
  Polypora sp.

Brachiopoda—
  Lingula cf. *ligea* Hall,
    ,, cf. *punctata* Hall,
  Chonetes subcancellata Reed,
    ,, cf. *sarcinulata* Schloth.,
  Camarotœchia sp. (*a*) and (*b*),
  Athyris cf. *spiriferoides* (Eaton).

Lamellibranchiata—
  Janeia birmanica Reed,

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[1] *Mem.*, XXXIX, Pt. 2, 238 (1913).

Phthonia loczyi Reed,
,, (?) cf. *lirata* Hall,
Prothyris cf. *lanceolata* Hall ?,
Ontaria ? sp.
Nucula wetwinensis Reed,
,, aff. *niotica* Hall,
,, cf. *bellistriata* Hall,
Palæoneilo cf. *plana* Hall,
,, cf. *elongata* Hall,
,, cf. *sulcatina* Conr,
Paracyclas cf. *proavia* (Goldf.),
,, cf. *rugosa* (Goldf.).

Gastropoda—

Bellerophon *shanensis* Reed.,
,, (*Phragmostoma*) *admirandus* Reed.

Trilobita—
Phaëtonides aff. *cyclurus* Hall,

Malacostraca—

Echinocaris asiatica Reed.

Pisces—

Ichthyodorulite.

This fauna of the Wetwin Shales is quite distinct in composition and specific characters from that of the Padaukpin limestone, but it is undoubtedly of Devonian age, and there are neither Silurian nor Carboniferous elements in it. The most abundant group of organisms is that of the Mollusca, while the Cephalopoda are entirely unrepresented. Especially characteristic and abundant are: *Janeia birmanica*, *Palaeoneilo* cf. *plana*, *Bellerophon shanensis* and *Chonetes subcancellata*. The general facies of the Wetwin fauna is unlike that of any known in Europe. On the other hand, the occurrence of many species allied to or identical with those of the Hamilton group in North America is of interest, and there are several forms allied to or perhaps identical with members of the Naples fauna of western New York, of Upper Devonian age (*Manticoceras intumescens* stage).[1] The Wetwin Shales, therefore, are referred provisionally either to the lower part of the Upper Devonian (Frasnian) or to the upper part of the Middle Devonian (Givetian), and the suggestion is made that they probably overlie the Padaukpin limestone. *Echinocaris* is characteristic of brackish if not of fresh water, as are probably also the fish remains, and the presence of these fossils seems to indicate the proximity of estuarine conditions.

Philipsastraea assemblage.—Three miles S.S.E. of Padaukpin village, in a small stream-course descending steeply to the Kelaung Chaung, a limestone lithologically similar to that at the village was discovered by Cowper Reed to be fossiliferous. The assemblage of fossils is, however, quite different from the

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[1] *Pal. Ind.*, New Ser., Vol. II, Mem. 5, 182 (1908).

Calceola fauna of the village outcrop, and represents the lower part of the Upper Devonian.[1] The following is a list of species found :

Actinozoa—
- *Phillpsastræa orientalis* (Stanley Smith),
  - ,, *padaukpinensis* Reed,
- *Endophyllum* cf. *priscum* (Münst.),
- *Cyathophyllum ceratites* Goldf., ? (*non.* Edw. & H.),
- *Striatopora* cf. *angulosa* Gürich,
  - ,, cf. *tchichatschewi* von Peetz.,
  - ,, cf. *suessi* Penecke,
- *Alveolites suborbicularis* Lam.,
  - ,, *ramosa* Roem.,
- *Aulopora serpens* Goldf.?
- *Favosites vicina* Reed.

Brachiopoda—
- *Orthis* (*Schizophoria*) *striatula* Schloth.,
  - ,, ,, *ivanovi* Tschern.,
  - ,, ,, cf. *hainensis* Maur.,
  - ,, (*Dalmanella*) *tioga* Hall,
- *Stropheodonta* (*Douvillina*) *imitatrix* Reed,
- *Orthothetes* (*Schellwienella*) *umbraculum* (Schloth.),
- *Atrypa reticularis* (Linné), var. *subauriculata* Reed,
  - ,, *douvillei* Mansuy, var.,

Chætopoda—
- *Spirorbis omphalodes* (Goldf).

The chief characters of this fauna are the presence of large masses of the coral *Phillipsastræa*, and the abundance of the three brachiopods : *Stropheodonta* (*Douvillina*) *imitatrix* (a new species), *Orthothetes* (*Schellwienella*) *umbraculum*, and a new variety (*subauriculata*) of *Atrypa reticularis*.

Other fossils.—A few poorly preserved corals have been found near the western edge of the plateau, south of Nyaungbaw, but though recognisable as *Cyathophyllum* or *Zaphrentis*, they cannot be identified with any of those from Padaukpin.[2]

Conditions of deposition.—The scantiness of insoluble residue in these limestones and their dolomitisation support the probability that they were formed under coral-reef conditions. La Touche remarks that " the practically complete dolomitisation of the great mass of the Plateau Limestone is an indication that deposition took place in a slowly subsiding area, whereby sufficient time was allowed for the mineralising agents present in the sea-water to have complete effect''. Shaly bands are probably more frequent among the limestones of the plateau than would appear at first sight, since their outcrops are liable to be washed out and filled in with the universal red clay that covers the ground. Some of the shales are carbonaceous, but the strings and pockets of coaly matter, which are not unusual in the Plateau Limestone outcrops, are thought by Coggin Brown to be infolded later Mesozoic deposits.[1] The coaly matter of Wetwin may be an example of this, in spite of the high dip of the associated strata. At Nam-tu the Plateau limestones are interbedded with reddish brown sandstones—an unusual feature.[2]

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[1] *Rec.*, LXII, 229-231 (1929).

[2] The large gastropod found at the foot of the great Kyaukkyan scarp has been identified by Cowper Reed as an Upper Ordovician *Maclurites*, and is not a Padaukpin form. [*Rec.*, XV, 438-440 (1931).]

(ii) MYITKYINA.

On the Yunnanese frontier in the northeastern corner of the Myitkyina district, from the neighbourhood of the Fen-shui-ling Pass northwards to the vicinity of Chueh-ho, greyish white brecciated limestones, corresponding to the dolomitic type of Plateau Limestone and building hills of 8,000 feet, are recorded by Murray Stuart.[3] They are associated with red, earthy, crinoidal limestones, and overlie a series of dark, unfossiliferous shales ("Pyehpat Shales").[4]

Further west, in the Kamaing sub-division of the same district, small outcrops of limestone are common. In places the rock approaches marble, in others it is brecciated and perhaps referable to the dolomitic type of the Plateau Limestone.[5]

(iii) YUNNAN.

In western Yunnan, the Plateau Limestone in its dolomitic facies is well developed and reaches very great but unknown thicknesses. It is seen, for instance, in both the Salween and Mekong valleys in the latitude of Myitkyina town, and in one or two isolated outcrops in the vicinity of these valleys.[6] It forms alternating bands with the calcitic variety, and is better exposed than it is in the Northern Shan States. As in the Northern Shan States, it is difficult to define the boundary line between the two types ; between the Yang-tze and the Salween both have been much infolded and in many cases altered.[7] The dolomitic limestones give rise to rugged scree-covered hill-tops or to vertical-sided cañons, in contrast to the wider valleys and gentler slopes of the calcitic types. The former have yielded very few fossils and their most striking feature is, as in Burma, universal brecciation and re-cementation ; their homogeneity prevents any attempt at sub-division. The prevailing type of rock is a light-coloured dolomite, of a finely granular appearance. On the Salween and Mekong, these beds appear to overlie the Kaoliang series, which is more or less equivalent to the Chaung Magyi, and contain crinoid stems ; they weather to a clayey soil which, however, is not red like the *terra rossa* of the Northern Shan States.

In northern Yunnan, on the north bank of the Yang-tse Kiang, four marching stages to the northeast of Ta-li Fu, the following Devonian fauna has been collected by Dr. Coggin Brown and determined by Dr. Cowper Reed : [8]

Actinozoa—
- *Favosites cognata* Reed,
- *Pachypora* aff. *polymorpha* Goldf.,
- ,, *retardata* Reed,
- *Campophyllum yunnanense* Reed.

Crinoidea—
- Crinoidal remains.

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[1] *Rec.*, LXXI, 170,—216 (1936).
[2] J. Coggin Brown. *Rec.*, XLVIII, 154 (1917).
[3] *Rec.*, LIV, 407 (1922).
[4] Gen. Rep. *Rec.*, LXVI, 89 (1932).
[5] *Rec.*, LXII, 108 (1929).
[6] J. Coggin Brown. *Rec.*, XLVII, 226 (1916).
[7] J. Coggin Brown. *Mem.*, XLVII, 54 (1920).
[8] *Pal. Ind.*, New Ser., Vol. X, Mem. 1, p. 7 (1927).

Brachiopoda—
Orthis (*Dalmanella*) cf. *bistriata* Tschern.,
,, aff. *gervillei* Defr.,
Chonetes orientalis Loczy, var. *admixta* Reed.,
,, *sarcinulata* Schloth., var. *yungpeensis* Reed,
Spirifer aff. *cabedanus* de Vorn.,
,, aff. *speciosus* Reed,
Atrypa reticularis (Linné) var.

Lamellibranchiata—
Conocardium sp.

Cephalopoda—
Orthoceras ? sp.,
Actinoceras sp.,
Sphyradoceras sp.

Trilobita—
Proetus mediospinosus Reed.

The most abundant fossils are *Campophyllum yunnanense*, the two species of *Chonetes*, and *Favosites cognata*. The beds are overlain by the Mesozoic Red Beds series with a conglomerate at the base.[1] West of Hui-li Chou, a brecciated limestone of Palaeozoic age is recorded by Coggin Brown, yielding a characteristic red soil. With these brecciated and re-cemented limestones of western Yunnan Professor J. W. Gregory associated, in his "Minchia series" of supposed Upper Devonian age, various black shales, purple, red and green sandstones and grits—some of them indurated to quartzites—and similar brightly coloured shalos which are occasionally phyllitic.[2]

In eastern Yunnan and other parts of China, the Lower Devonian is represented by continental deposits carrying a few plant remains. A continental facies also characterises the Lower Devonian of Indo-China which contains fish remains and the plant *Arthrostigma gracile* Daws. The Eifelian and Givetian of the Middle Devonian as well as the Frasnian and Famennian of the Upper Devonian are all present in eastern Yunnan, and are all very fossiliferous, the faunas showing little variation from one point to another over considerable distances. Pure limestones are exceptional and the rocks are said to be of sandy, marly or shaly-calcareous types.[3] The forms from the Yunnanese Eifelian, like those of the Padaukpin fauna of the Northern Shan States, show close affinity with species of the same age in the Rhenish provinces. Of the corals found in the Padaukpin fauna, all the species occur in the Chinese Devonian or are represented by related forms ; of the specifically identified brachiopods from Padaukpin no less than 25 per cent. occur in China, while an additional 34 per cent. are represented by varieties or by closely related species, according to Dr. A. W. Grabau.[4] Much the same early Middle Devonian fauna has been recognised in parts of Sze-chuan and southern Kansu.

(iv) KYAUKSE DISTRICT.

The western edge of the Shan plateau, as it extends southwards, passes through the eastern parts of the Mandalay and Kyaukse districts, a deeply-dissected portion of its fringe in the latter area being known as the Ye-Yaman Tract. The western portion of this tract is occupied by compact, dolomitic varieties of the Plateau Limestone ; eastwards it gives place to a series of shales, phyllites and sandstones —the Sindetaung Shales—which are thought to underlie the Plateau Limestone with considerable unconformity and may bclong perhaps to the Chaung Magyi series.

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[1] *Rec.*, LIV 325 (1922).
[2] ***Phil. Trans.*** Ser. B ,Vol. 213, p. 220 (1925).
[3] J. Coggin Brown. *Mem.*. XLVII, 55(1920).
"The stratigraphy of China", Vol. I. p. 157 (1924).

(v) MEIKTILA, YAMETHIN AND THE SOUTHERN SHAN STATES.

Physiography.—Though thrown into ridges and minor mountain chains, the limestone plateau of the Southern Shan States has a general elevation which gives it the same cool climate which the Northern Shan States enjoy for several months in the year. Middlemiss describes the plateau as follows : " In its essentials, and not considering the younger minor zones that are inlaid with it, it is a rugged rocky country. The dark grey limestone frequently weathers almost black into sharp-edged honeycombed masses, into pinnacled crags and weather-beaten towers and walls ; into deep basins and swallow-holes (often as regular and circular in outline as a gigantic amphitheatre, but sometimes funnel-shaped) ; into strange valley systems without connection one with the other, and that often end mysteriously either as underground passages down which streams precipitate themselves and become lost, or as marshes and lakes where evaporation, helped out no doubt by subterranean percolation, causes a disappearance of the waters into innumerable caves and passages beneath the ground, some now high and dry from the waters that caused them and which are locally mined for the nitrates that have accumulated upon the floors from the decomposition of cave animal deposits ;" some of these underground chambers, rich in the beauty of stalactitic growths, are used as temples.[1] Except in upland valleys and deep gorges, the sponge-like absorption of the rainfall carries off nearly all the surface water, a great deal of which is probably led away by underground river systems. In this respect, with its steeply-graded slopes black with the ashes and charred remains of the ever-prevalent forest fires, with its stems of stunted forest trees, the country of the Plateau Limestone forms a striking contrast to the gneissic and metamorphic zone which is well supplied with water.

Paunglaung range.—From the plains of Meiktila and Yamethin rises sharply the western edge of the wide hilly zone of gneissic and metamorphic rocks. This is succeeded by a belt of Mesozoic beds from which protrudes a narrow inlying band of grey, unfossiliferous Plateau Limestone, dipping at a steep angle and forming the main hill range to the east of Pyin-nyaung. This band can be seen, some six miles west of the hill station of Kalaw, stretching north and south for many miles, overlooking the Paunglaung river, as a well-developed hill range capped by the sharp, rugged crags and chimneys towering over 6,000 feet above sea-level, so familiar to passengers on the railway between Lebyin and Sintaung.[2] The limestone of this band has no definite bedding and is slightly brecciated, the fragments being re-cemented by the usual calcite veins. It is underlain by a series of sandstones and shales, unfossiliferous but possibly Silurian in age,[3] and upon it rest unconformably the Loi-an Coal Measures of the Jurassic (? Rhaetic).[4]

Hsa-Möng-Hkam band.—The great limestone plateau becomes definitely recognisable a little to the east of Kalaw. Occurring at first as inliers folded up with the Loi-an Coal Measures, the Plateau Limestone outcrop extends eastwards underneath the broad lake-like expanse of the Hsa-Möng-Hkam (Thamakan) plain as far as another similar alluvial expanse, *viz.*, that of the He-ho plain. Northwards it extends through the State of Poila (Pwela) into that of Pindaya (Pangtara), where it is interrupted by a broad inlicr of Ordovician and Silurian beds. This large irregular tract of the Plateau Limestone has a general N.N.W.-S.S.E. trend ; characterised by rolling downs, it forms at the same time all the great mountain peaks of the area. The rock is sometimes massive, at other times thin-bedded, and shows no great metamorphism. In the neighbourhood of the Loi-an coalfield, it is described as a grey, much crushed, dolomitic limestone, containing about 20 per cent. of magnesium oxide, with traces of crinoids and other unidentifiable fossils ;[1] these exposures, dipping usually at angles of 60° or 70°, evidently belong to the dolomitic type. The high dips are apparently local, since the Plateau Limestones, which fringe the Loi-an coalfield on the east and extend under the Hsa-Möng-Hkam plain to reappear in the Hsa-Möng-Hkam range further east, are described as folded into gentle, more or less N.S. folds.[2] The limestone formation is covered by the usual cap sometimes as much as 50 feet thick, of the "*terra rossa*" which is so universal in the Northern Shan States. At Poila the limestone has yielded a rather abundant coral belonging generically either to *Syringopora* or *Tetrapora*.[3] Most of the limestone of the Hsa-Möng-Hkam tract belongs to the dolomitic type, but some unusual varieties are to be found in the neighbourhood near Lwekaw.

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[1] *Gen. Rep.*, 1899-1900, 130-131

[2] Ibid. *Rec.*, LXVII, 481933).

[3] Ibid. *Rec.*, LVIII, 43-44 (1925).

[4] Ibid. *Rec.*, LXIX, 59 (1935).

Lawksawk.—Plateau Limestone, mostly of the dolomitic variety, covers a considerable area in Lawksawk State. From a succession of well-bedded limestones, shales, highly argillaceous limestones and sandstones, about a mile east of the village of Htangtabin, Dr. M. R. Sahni has collected numerous fossils.[4] The same fauna, which is evidently close to that of Padaukpin, has been found a mile or two to the southeast, near Taung-tek. In fact, fossils can be picked up at several places along the scarp between these two localities, rivalling in their perfection the specimens obtainable from the classical ground of Padaukpin. Among the fossils obtained from Taung-tek, Me-so or the hill-slopes between these two localities, Dr. Sahni has identified the following:[5]

Actinozoa—
 Pachypora sp.,
 Fenestella sp.

Bryozoa—
 Favosites sp.

Crinoidea—
 Lophocrinus ? sp.,
 Taxocrinus ? sp.

Brachiopoda—
 (p) *Reticularia curvatus* (Schloth.),
 (p) ,, *aviceps* Kays.,
 (p) *Spirifer speciosus* Schloth., var. *mesoensis* Sahni.
 (p) *Cyrtina heteroclIta* Defr.,
 (p) *Atrypa reticularis* (Linné.),

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[1] *Rec.*, LV, 34 (1923).
[2] *Rec.*, LXIII, 86 (1930).
[3] F. R. Cowper Reed. *Rec.*, LXVII, 118 (1933).
[4] *Rec.*, LXXI, 26 (1936).
[5] Private communication ; *see* also *Rec.*, 173, 29 (1938).

(p) *Leptæna rhomboidalis* Wilck.,
(p) *Orthis* (*Schizophoria*) *striatula* Schloth.,
Stropheodonta cf. *subtrigona* Roem.,
Rhynchonella thannooensis Sahni,
Pentamerus sp.,
Chonetes sp.,
Productella (3 species),
Meristella palaungensis Sahni.

Gastropoda—
Pleurotomaria lihsawensis Sahni.,
Platyceras kachinensis Sahni.
Trilobita—
Calymene cf. *malaungkaensis* Mansuy (Devonian of Tonkin).
(p)=Padaukpin forms.

The genus *Calymene* has so far not been found elsewhere in the Devonian of the Shan States. With the exception of the well-known *Atrypa* and *Leptæna*, which are found also in the Silurian, this fauna is characteristic of the Middle Devonian, although the zone fossil, *Calceola sandalina*, has not yet been discovered. The beds are separable into two divisions, a lower in which *Atrypa reticularis* occurs profusely, and an upper in which this brachiopod is absent ; at the top of the upper division is a dark, compact limestone yielding a species of *Favosites* and other fossils difficult to extract.

Taung-gyi-Htamsang tract.—East of the He-ho plain is the He-ho Limestone, which is believed to be the equivalent of the Mawsön and which extends eastwards as far as the Sinhe or Yawnghwe plain. On the other side of the latter, Pindaya beds and, further on, Plateau Limestone beds, begin the ascent to the hill station of Taung-gyi (4,675 feet). This broad tract, with a general altitude of 4,500 feet, enveloping the Pindaya inliers of Taung-gyi and Ho-pong, includes both types of the Plateau Limestone formation in alternating bands, and from one of the Permian bands near Htamsang a copious collection of fossils has been made. In this tract there is an unusual number of enclosed valleys, disappearing streams and sink-holes ; southwards, a little to the east of Namhkok, the rock gives rise to the usual fantastic peaks and great chimneys. The predominant varieties are grey, brecciated dolomites, sometimes friable, oftener hard and re-cemented, with the characteristic sandy appearance.[1] The lower slopes of Taung-gyi are built up of much-crushed and brecciated limestone re-cemented into a kind of angular concrete. The Permian bands will be described in their place (pp.702-705).

Wanpong-Melawn belt.—Further eastwards, near Möng Pawn, a thin band of the Permian variety of the Plateau Limestone is exposed. Continuing in the same direction, the Plateau Limestones reappear at Wanpong, and again occupy undulating downs drained by enclosed valleys and sink-holes. Between Wanpong and the Salween river there are, in fact, three or four tracts of these beds, separated from each other by strips of Mesozoic rocks ; the limestone is again seen to the east of the river. Around Möng Nai are many picturesque pagodas perched on pinnacles of the dolomitic limestone ; some of the local varieties of the latter are as white as chalk and at times so shattered that roadside cuttings fall to powder on exposure and slip down in shoots of calcareous sand.[1]

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[1] Gen. Rep. *Rec.*, LXVI, 98 (1932).

Other extension.—Plateau Limestone caps the high levels of the Chaung Magyi rocks on both banks of the Salween river, and a narrow strip has been recognised in the extreme southeast of the Keng Tung State, close to the frontier village of Ta Hki-lek, expanding rapidly southwards in Siamese territory to occupy hundreds of square miles.[2]

The Plateau Limestone also extends into the small sub-States of Myin-mu and Nam Hkom,[3] and southwards into Karenni. In Möng Hsu State (Naking), it is the predominant rock and forms the vertical-sided tops of most of the hills. With this exception, the geology, which is thought to be somewhat disturbed, is concealed by a thick layer of the red clay which so frequently accompanies the Plateau Limestone in the Northern Shan States and elsewhere. The limestone is here a pale grey to black rock, seldom showing any bedding, and usually much crushed and re-cemented by white bands or veins of calcite.[4] There are many exposures of Plateau Limestone in the Keng Tung State; one of these shows a small vein or pocket of stibnite. Most of the hills in Möng Kung State are formed of Plateau Limestone.

Comparison with the Northern Shan States.—In the Southern Shan States, therefore, where the Paleozoic succession is more complete and more widespread than it is in the north, both types of the Plateau Limestone are present. The calcitic type is better displayed and has yielded more varied faunas than in the north; it will be described later on. The other type, which is often buried under thick accumulations of residual deposits, differs in no way from that found in the Northern Shan States. It is generally a white or light grey dolomite, weathering to a darker colour, always exceedingly brecciated; where the secondary filling which cements the rock together has been leached out, the result is a shattered rock easily broken into fragments. The shattered character of this rock lends itself to an extensive use as a road dressing.

A younger dolomitic division.—In the Northern Shan States there is fossil evidence, as we have seen, to show that some at least of the dolomitic type of limestone is older than the Permian. In the Southern Shan States, on the other hand, there is reason to suspect that some—perhaps much—of the dolomitic variety belongs to the higher portions of that system. In the region between Kalaw and Taung-gyi, Coggin Brown and Sondhi found that the boundary rock of the Plateau Limestone formation, where in contact with bands of Silurian or Ordovician, belongs, not to the dolomitic, but to the calcitic type; in some places, fossiliferous bands belonging to this type appear to dip under the dolomitic variety. We may be prepared to find, as a result of further investigation, therefore, that the Plateau Limestone formation of Burma is threefold, consisting of a middle division of Lower or Middle Permian marls, mudstones and pure, tabular, non-magnesian, frequently fossiliferous limestones, separating an upper from a lower division, each characterised by dolomitic, brecciated, mostly unfossiliferous limestones. How much, if any, of the dolomitic, brecciated variety in the Northern Shan States belongs to the upper division, it is impossible to say. That much of the dolomitic variety in the Southern Shan States belongs to the uppermost of the three divisions is more than probable ; in fact, the lowest division seems to be entirely missing in places where the Permian division rests stratigraphically upon older Palaeozoic rocks. The existence of an upper dolomitic division would account for the failure of La Touche to find any trace of the calcitic Permian limestones along the edge of the tongue of Plateau Limestone extending northwards along the east bank of the Nam Tu, where the latter formation appears to dip conformably below the red Jurassic sandstones ; where the calcitic Permian beds are seen almost in contact with red sandstones—as is the case at Kehsi Mansam—the section lies on the line of a fault and is greatly confused.[1] The individuality of the two types of Plateau Limestone is itself not beyond suspicion and La Touche mentions one locality, Tonbo, at the extreme western edge of the hills in the district of Mandalay, where a band of the calcitic limestone, containing a number of specimens of a fusulinid appears to pass laterally as well as vertically into crystalline limestone indistinguishable from the usual dolomitic type. The fusulinid has been determined by Diener as *Fusulina elongata* Shumard, indicating a "Permo-Carboniferous" (Lower Permian) age, but Professor C. O. Dunbar identifies the sections as those of a species of *Polydiexodina* and would prefer to correlate the horizon with the Upper Permian of America.[2] The Tonbo area, therefore, appears to be one where the higher-lying portions of what looks like the ordinary dolomitic type of Plateau Limestone range well up into the Permian. That there were, generally speaking, breaks in deposition between the two types of limestone, one of them corresponding to some horizon of the Permian period—perhaps the Middle Productus beds of the Salt Range—seems indicated by the absence of dolomitization throughout what is suggested to be the middle division. If the suggested threefold sub-division stands the test of future investigation, the upper division will probably have to be assigned to the higher Permian ; whether the lowest division includes any of the Carboniferous, or the latter period is entirely represented by some not always very evident break between the lower and middle divisions, is a question which will be satisfactorily solved only by the discovery of restrictively Carboniferous fossils. As Dr. Coggin Brown has pointed out, that there was continuous marine deposition from the Devonian to the base of the Trias in a region which has been notably unstable throughout geological time does not appear probable.

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[1] J. Coggin Brown and V. P. Sondhi. *Rec.*, LXVII, 160-161 (1933).

[2] Gen. Rep. *Rec.*, LXIX, 59 (1935).

[3] Ibid *Rec.*, LXV, 89 (1931).

[4] Guy E. Pilgrim and W. D. West. *Rec.*, LIII, 47 (1921).

Recently, the Plateau Limestone has been traced through North Hsenwi as a narrow belt, striking N.E.-S.W. and dipping generally at a low angle. No occurrence of the calcitic variety has so far been encountered. The bulk of the formation is as usual unfossiliferous and uniformly dolomitised, the only organic remains hitherto recorded being those of a fusulinid allied to *Schwagerina*, which has been recorded by Dr. M. R. Sahni from near Kutkai in the Northern Shan States and from the vicinities of Mo-so-ma-ye and Kong Tawnghsu in the Southern Shan States (Lawksawk), and is therefore widely distributed[3].

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[1] *Mem.*, XXXIX., Pt. 2 257 (1913).

[2] *Rec.*, LXVI, 408 (1932).

[3] *Rec.*, LXVI, 96 (1932) ; *Ibid.*, LXVII, 46 (1933) ; *Ibid.*, LXVIII, 58 (1934) ; *Ibid.*, LXIX, 22, 54, (1935).

B. CALCITIC TYPE OF THE PLATEAU LIMESTONE.

Limited extent.—In the Northern and Southern Shan States, whereas the dolomitic type of the Plateau Limestone covers extensive tracts of country, the calcitic variety, formerly spoken of as the " Permo-Carboniferous ", occurs, generally speaking, in relatively small outcrops.

(i) NORTHERN SHAN STATES.

Mode of occurrence.—At various places on the Shan plateau, especially towards the southeast of the Northern Shan States, are to be found patches of limestone of a character different from that of the great bulk of the Plateau Limestone ; these outlying masses occur as rugged, precipitous walls of rock, capping ridges and knolls, the main mass of which is built of the dolomitic variety[1]. They are true non-magnesian limestones, tough and compact, usually dark blue, grey or black in colour, minutely crystalline in texture, with a specific gravity of about 2·69[2] ; they do not exhibit the superficially sandy texture so characteristic of the more prevalent type of Plateau Limestone, are more compact, often possess a conchoidal fracture, and have a much more strongly fœtid odour. In many places these rocks are highly fossiliferous, and thin sections under the microscope in most cases show the presence of shell fragments and foraminifera As already noted, evidence is not wanting that the dolomitic and calcitic types of the Plateau Limestone sometimes pass laterally as well as vertically into one another. Be this as it may, in several places on the plateau the difference in appearance is described as easily recognizable and the boundaries of each patch of the calcitic type are well defined.

Origin.—To what extent the change in character between the two types of the Plateau Limestone is due to a difference in age, to some local peculiarity in the conditions of accumulation of the sediments resulting in a particular assemblage of organisms, or to a difference in the treatment to which the last beds to be accumulated were subjected after their deposition, it is not yet possible to say. La Touche remarks that the calcitic patches may have been of the nature of reefs supporting an abundant brachiopod and coral fauna, while the surrounding sea was occupied mainly by mollusca with their more easily decomposed shell structure. In any case, the fact that these particular beds are composed of practically pure calcium carbonate, whereas the whole of the subjacent mass has been converted into a dolomitic limestone, indicates a complete change in the history of accumulation. La Touche has suggested that the long continued subsidence which must have accompanied the deposition of so enormous a thickness of rock, was replaced by a comparatively rapid upheaval ; whatever the cause, the change seems to have been marked in some places by a break in deposition.

Relations to the Succeeding Namyau Beds.—Along the edge of the tongue of Plateau Limestone which extends northwards along the eastern bank of the Nam Tu, where these beds appear to dip conformably below the red Jurassic Namyau sandstones, and where, therefore, we might expect a complete sequence, no trace of the calcitic limestones has been found. Since, however, there was certainly some denudation of the Plateau formation before the Namyau series was deposited, it is possible that this apparently conformable relationship is accidental and that the topmost limestone beds were eroded away before the Namyaus were laid down ; if not, we must accept the suggestion already put forward that some of the dolomitic varieties of the limestone are considerably later in age than occurrences elsewhere.

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[1] T A. D. La Touche. *Mem.*, XXXIX, Pt. 2, 256 (1913).
[2] J. Coggin Brown and V. P. Sondhi. *Rec.*, LXVII, 207 (1933)

The Namun Fauna.—In the Northern Shan States, the presence of Permian ("Permo-Carboniferous ") rocks was first discovered by P. N. Datta in a *Fusulina*-bearing limestone band at the crest of a ridge a few miles west of the Tong-Ang ferry on the Nam Tu river, and still further to the east at Ho-un. Other exposures of limestone with *Fusulina*, and in some cases with a comparatively rich brachiopod and bryozoan fauna in addition, prove the former existence of strata of Permian age over a large area in the Northern Shan States. One of the chief fossil localities of this area is Namun, from which Diener has identified[1] :

Crinoidea—
    Crinoid stems.

Bryozoa—
    Hexagonella ramosa Waag. and Wentz. (M. U.),
    Geinitzella [*Batostomella*] cf. *columnaris* Schloth. (M.U.),
    Fenestella cf. *perelegans* Meek. (M.),
        ,, aff. *geinitzi* d'Orb.,
    Polypora cf. *ornata* Waag. and Pichl. (M. U.),
        ,, cf. *biarmica* Keyserl. (U.),
        ,, cf. *megastoma* de Kon. (M. U.),
        ,, aff. *kolwœ* Stuck.,
        ,, aff. *ufimiana* Stuck.,
        ,, ? aff. *sykesii* de Kon. (L. M.),

Brachiopoda—
    Spirifer (*Neospirifer*) *fasciger* Keyserl. (equated by Diener with *S.* (*N.*) *moosakhailensis* Dav., a common fossil in the Middle and Upper Productus Limestone of the Salt Range, considered by some to be a variety of *S. fasciger* Keyserl.) (? M. ? U.).
        ,, aff. *striatus* Mart.
    Martinia sp.
    Spiriferina (*Spiriferellina*) *cristata* Schloth. (M. (Variety)) (according to Cowper Reed, more like *S.* (*Spiriferellina*) *subcristata* Netsch.)
    Streptorhynchus (*Schuchertella*) cf. *semiplanus* Waag. (M. U.)
    Orthis (*Schizophoria*) *indica* Waag. (L. M.)
        ,, (*Rhipidomella*) *michelinii* L'Eveillé.
    Productus cf. *boliviensis* d'Orb.
        ,, aff. *scabriculus* Mart.
        ,, cf. *pustulatus* Keyserl.
    Strophalosia (*Heteralosia* ?), aff. *plicosœ* Waag. (L.)
    Chonetes (*Dienerella*) aff. *squamulifera* Waag. (M.)
        ,, cf.. *lœvis* Dav.
        ,, cf. *variolata* d'Orb.
    Notothyris nucleolus Kut.

Lamellibranchiata—
    Aviculopecten aff. *subfimbriatus* Vern. (M.)

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[1] *Pal. Ind.*, New Ser.. Vol. III. Mem. 4, (1911).

The mother rock is a dark impure limestone in which the fossils occur packed so closely together as to make it difficult to develop complete specimens; the commonest forms are bryozoa. Species marked "L", "M" or "U" are found in the Lower, Middle or Upper Productus Limestone, respectively, of the Salt Range.

Fossil Localities.—Places in the Northern Shan States in which fossils have been found are: the Namun locality; Tonbo, at the edge of the Irrawaddy valley, thirteen miles southeast of Mandalay; the valley of the Nam Tu, south of Hsipaw (Tong-Ang ferry and Namlan); Ho-un, five miles northeast of Lio-pan; Man-kang, on the northern slope of the Loi-len range, about twelve miles east of Lashio; Man-naw, in the valley of the Nam Lawng, whence a broken line of outcrops has been traced northwards for some twelve miles; the natural bridge on the Nam Lan river, one of the southern tributaries of the Nam Tu, near Nanio; across the Nam Lawng, on the crests of the ridges about Man Pung; and again still farther east, on a ridge to the southwest of Man Hpai. In the last-mentioned area the *Fusulina* band rests on the ordinary dolomitic Plateau Limestone, and is succeeded above by red shales belonging to the Namyau series, faulted against the limestone as at Kehsi Mansam in the Southern Shan States[1].

In the bed of the Nam Tu at Htengnoi, south of Hsipaw, are limestones with poorly-preserved fragments of a *Fusulina* differing from *F. elongata*; these beds have been traced for two or three miles to the north. Dipping at 20° to 30°, they appear to be succeeded below by thick beds of conglomerate which rest upon steeply-inclined beds of the massive dolomitic Plateau Limestone. It is possible that the conglomerates, which contain well-rolled pebbles of the Plateau Limestone, have been let down from a higher level by solution of the limestone beneath. Whatever has happened, it seems evident that the *Fusulina*-bearing limestones are referable to the Upper Carboniferous or the Permian.

(ii) MYITKYINA DISTRICT.

As already noted, small outcrops of limestone are common in the Kamaing subdivision of the Myitkyina district, and include brecciated examples of the dolomitic type of the Plateau Limestone. In other places the rock approaches marble. At the confluence of the Hwekha and Nammon Streams, the limestone near its contact with the peridotites and serpentines has been metasomatically silicified and, under the microscope, shows a very fine mosaic of silica with perfectly developed rhombohedra of dolomite and specimens of *Fusulina elongata* and *Textularia*; it is evidently of Upper Carboniferous or Permain age[2].

(iii) SOUTHERN SHAN STATES.

Kehsi Mansam fauna.—The Permian is better developed in the Southern than in the Northern Shan States. A section of these rocks, exposed in the bed of the Nam Hen, about a mile southwest of the town of Kehsi Mansam and eleven miles southeast of Möng Tung, is not so complete as that seen farther south, but contains a richer assemblage of fossils. The beds occur in the vicinity of a considerable fault, and one junction is concealed by a calcareous dam and a deep pool, while the other is an abutment, probably faulted, against massive beds of the ordinary dolomitic Plateau Limestone. The dark, thin-bedded Permian limestones have apparently been let down between two parallel faults, becoming much folded and crushed in the process. Some of the layers are made up almost entirely of *Fusulina elongata*, while others contain large numbers of brachiopods. The fauna from this area, identified by Diener, is, with a few modifications, as follows :[1]

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[1] T. H. D. La Touche. *Mem.*, XXXIX, Pt. 2, 262 (1913).

[2] *Rec*, LXII 108 (1929).

Foraminifera—
Fusulina elongata Shumard.

Actinozoa—
Lonsdaleia [*Waagenophyllum*] *indica* Waag. and Wentz. (M. U.)
Amplexus sp.,
Zaphrentis sp.

Crinoidea—
Crinoid stems.

Bryozoa—
Polypora sp.

Brachiopoda—
Spirifer (*Neospirifer*) *fasciger* Keyserl. (equated by Diener with *S.* (*Neospirifer*) *moosakhailensis* Dav.) of the Salt Range, Kashmir and Central Himalaya. (?M. ?U.)
,, *striatus* Mart.
,, *condor* d'Orb.
,, (*Spiriferella*) aff. *saranœ* de Vern. (L.)
Martinia dispar Dien.,
,, *orbicularis* Gemm.,
Reticularia cf. *lineata* Mart. (possibly the equivalent of *Squamularia* (*Neophricodothyris asiatica* Chao, a form found in the Middle Productus Limestone) (?M.).
Martiniopsis latouchei Dien.,
Spiriferina (*Spiriferellina*) *cristata* Schloth. (M. variety).
,, aff. *laminosa* McCoy, *var. sterlitamakensis* Tschern.
Athyris (*Cleiothyridina*) "*royssii*" L'Ev. (*Athyris royssii* ("*Spirigera royssii* ") has been split by Cowper Reed into more than one species). (L. ?., M.? U.?)
Spirigerella derbyii Waag, var. *acutiplicata* Waag., (M. U.)
,, n. sp. aff. *numismalis* Waag. (L.)
Hustedia remota Eichw. (probably equivalent to *H. grandicosta* (Dav.)., found in the Middle Productus Limestone) (?M).
Derbyia ["*Streptorhynchus*"] *shanensis* Dien. [*Rec.*, LXVII, 86, (1933).]
Orthis (*Schizophoria*) cf. *indica* Waag. (L. M.)
,, (*Rhipidomella*) *imitatrix*, (Dien.),
Oldhamina cf. *decipiens* de Kon. (M.)
Prodaclus (*Linoproductus*) *cora* d'Orb. (U.—variety),
,, ,, *tenuistriatus* de Vern.
,, (*Avonia*) *wallacei* Derby, var. *burmana* Dien.,
,, (*Dictyoclostus*) "*semireticulatus*" Mart. (?),
,, cf. *inflatus* McChesn.,
,, cf. *boliviensis* d'Orb.,

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[1] *Pal. Ind.*, New, Ser., Vol. III, Mem. 4 (1911).

Productus aff. *porrectus* Kut.,
  ,, cf. *nebrascensis* Owen (perhaps *P.* (*Tschernyschewia*) *vicinalis* Reed, from the Middle and Upper Productus Limestone of the Salt Range),
  ,, (*Waagenoconcha*) *abichi* Waag. (M. U.),
  ,, (,,) *cylindricus* Waag. (U.—variety).
  ,, aff. *mammatus* Keyserl.,
Strophalosia (*Strophalosiina*) *costata* Waag. (L. probably Reed's variety *subrotunda*, from the Lower Productus Limestone.)
  ,, cf. *indica* Waag. (M. U.)
  ,, cf. *horrescens* de Vern. (?M.)
Dielasma (*Heterelasma*) *biplex* Waag. (M. cf. Reed's variety *protracta*)
Notothyris simplex Waag. (M.)
Camarophoria cf. *purdoni* Dav., (M. U.)

Lamellibranchiata—
  Pseudomonotis sp.

Scaphopoda—
  Antale or *Entalis*(?) sp.

Species found in the Lower, Middle and Upper Productus Limestone of the Salt Range are marked "L", "M" and "U", respectively.

Country between Taung-gyi and Mong Pawn.—As already noted, from Taung-gyi eastwards, the sequence is mainly a limestone one, belonging mostly to the Plateau Limestone group as far as Mile 28-3 on the Government cart road, where the latter ends at the crest of the ridge between the two Shan States of Hopong and Möng Pawn. Both types of the Plateau Limestone are represented, the calcitic by thin-bedded, tabular concretionary bryozoan limestone with interbedded marly and shaly layers[1]; the latter are in places packed with fossils, including bryozoa, brachiopods and corals. From a black shattered variety of the limestone near Taung-gyi, the Salt Range coral, *Lonsdaleia* [*Waagenophyllum*] *indica* Waag. and Wentz., has been obtained but unaccompanied by any other fossil. Between Mile 20 and the above-mentioned ridge, the sequence consists apparently entirely of Permian beds, with the possible exception of a band of the older brecciated limestone recorded by Middlemiss[2]. The most important fossil localities are situated near Miles 23-7, 24-1 and 28-3, the brachiopods from the last including species of *Productus* and *Lyttonia*. As in the Northern Shan States, these limestones occur immediately above the massive, white and grey, often brecciated dolomitic limestones.

Fossils collected by Middlemiss from beds of this age between Hopong and Möng Pawn have been indentified by Diener as follows[3];

Actinozoa—
  Amplexus sp.,
  Michelinia (?) sp.,
  Cyathaxonia sp.

Crinoidea—
  Crinoid stems.

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[1] *Rec.*, LXVI, 98 (1932).
[2] *Gen. Rep.*, 1899-1900. p. 138.
[3] *Pal. Ind.*, New Ser., Vol. III, Mem. 4, 70-71 (1911).

Bryozoa—
Fenestella sp.,
Thamniscus vel *Acanthocladia* sp.

Brachiopoda—
Spirifer (*Neospirifer*) *fasciger* Keys. (probably equivalent to *S.* (*N.*) *moosakhailensis* Dav.).
Martinia sp.,
Spiriferina (*Spiriferellina*) *cristata* (Schloth) (?. M.—variety)
Athyris (*Cleiothyridina*) "*roysii*" L'Ev. ("*Spirigera royssii*") (L. ? M. U.)
Spirigerella derbyii Waag. (M. U.)
Orthis (*Schizophoria*) cf. *indica* Waag. (L. M.)
Productus cf. *boliviensis* d'Orb.,
Chonetes cf. *lævis* Dav.
,, (*Dienerella*) *grandicosta* Waag. (M—variety)
Uncinulus cf. *timorensis* Beyr. (species equated by some with *Uncinunellina theobaldi* (Waag.)) (?M.).
Dielasma plica Kut. (L. M. U.—variety) (closely resembles *D.* (*Heterelasma*) *shumardianum* Girty),
,, sp.
Marginifera aff. *helica* (Abich.) (?L.)
,, aff. *typica* Waag.(?) (M. U. ? variety)

Trilobita—
Phillipsia aff. *middlemissii* Dien.
U.=species found in the Upper Productus Limestone.
M.=species found in the Middle Productus Limestone.
L.=species found in the Lower Productus Limestone.

From a locality near the 24th milestone on the above road from Taung-gyi to Möng Pawn, Dr. Cowper Reed obtained a fauna which has much in common with Middlemiss' more promiscuous collections, as well as with the Namun fauna of the Northern States ; it includes[1] ;

Brachiopoda—
Derbyia ? sp. (the doubtful *Streptorhynchus* of Kehsi Mansam),
Marginifera bivius Reed (perhaps identical with Mansuy's *Productus tuberculatus* Möll, mut. *orientalis*).
Aulosteges cf. *tibeticus* Diener ? (probably the same as Diener's *Strophalosia costata* from Kehsi Mansam).

Bryozoa—
Fenestella jabiensis Waag. & Pichl. (Salt Range form—Middle Productus Limestone),
Polypora cf. *tranninhensis* Mans. (Species found in Laos),
Streblotrypa bassleri Reed, .
Rhabdomeson submurale Reed.

Anthozoa—
Michelinia cf. *yunnanensis* Reed.

The Htam Sang locality.—A more copious collection was made by Dr. Coggin Brown from dark, thin-bedded, concretionary limestones and interbedded marly layers, all packed with bryozoa, corals and brachiopods, at Htam Sang, a village which is situated at Mile 25-3 on the same road between Hopong and Möng Pawn, and seems to have furnished some of Middlemiss' specimens[1]; as identified by Dr. Cowper Reed, this assemblage resembles in many respects that of Kehsi Mansam and comprises[2]:

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[1] *Rec.*, LXVII 120—126 (1933).

Lamellibranchiata—

- *Liebea indica* Waag. (L.)

Brachiopoda—

- *Derbyia grandis* Waag. (M. U.).
  - ,, *shanensis* (Diener) (found at Kehsi Mansam).
- *Streptorhynchus* cf. *pelargonatus* Schloth. (perhaps identical with *S.* cf. *semiplanus* Waag from Namun; *S. semiplanus* occurs in the Upper Productus Limestone) (M. U. ?),
  - ,, cf. *capuloides* (Waag.) ("*Orthothetes* cf. *capuloides*") (L. M.)
  - ,, (*Schuchertella*) *semiplanus* (Waag.) (Waagen's "*Orthothetes semiplanus* of the Salt Range) (M.),
- *Kiangsiella pectiniformis* (Davidson) ? ("*Streptorhynchus pectiniformis*"), (M.)
- *Strophalosia* sp.,
- *Productus* (*Krotovia*) cf. *janus* Huang (Species found in S. W. China; probably identical with the Chitral form, *P.* cf. *pseudoaculeatus* Krot.),
- *Productus* (*Dictyoclostus*) sp. (group of *semireticulatus*).
- *Marginifera* cf. *kweichowensis* Huang (Species found in S. W. China),
- *Chonetes* sp.
- *Camarophoria* cf. *nucula* Schwellw. (has resemblance to *C. globulina* Phill. of the Upper Productus Limestone).
- *Spiriferina* (*Spiriferellina*) *shanensis* Reed,
  - ,, (*Reticulariina*) *conquisita* Reed,
- *Squamularia* (*Neophricodothyris*) *asiatica* Chao "*Reticularia lineata* (Martin)" (M.)
  - ,, *duplex* Reed,
- *Martinia dispar* Dien.?
- *Martiniopsis latouchei* Dien.?
  - ,, cf. *subpentagonalis* Waag. (L.)
- *Notothyris exilis* Gemm.,
  - ,, *nucleolus* (Kut.) (Very close to *N. prælecta* Reed of the Middle and Upper Productus Limestone; a variety of *N. prælecta.* occurs in the Lower Productus Limestone) (? M., ? U.).
  - ,, *persimilis* Reed (probably identical with *N.* cf. *mediterranea* Gemm. from the Permian of Timor),
- *Athyris* (*Cleiothyridina*) *pectinifera* (Sow.) (probably identical with many of the shells in Asia referred to *A. royssii*). (M. U.)
- *Spirigerella derbyii* Waag., var. (M. U.)
  - ,, *prælonga* Waag., var. *shanensis* Reed (*forma typica* and a different variety in the Upper Productus Limestone) (U.).
- *Lyttonia nobilis* Waag. (found in the Salt Range, Timor, Indo-China, etc.) (M. U.)

Bryozoa—

- *Fenestella gemmata* Reed,
  - ,, *multinodulosa* Reed (perhaps identical with Diener's *F. perelegans* Meek from Namun),

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[1] From this neighbourhood Middlemiss obtained: *Spirifer musakheylensis*, *Productus* cf. *indicus*, *Spiriferina cristata*, and a large number of *Chonetes*, including *C. grandicosta* and *C. dichotoma* [*Rec.*, LXVII, 139-140 (1933)].

[2] *Rec.*, LXVII, 86-117 (1933).

Polypora koninckiana Waag. & Pichl. var. nov. *postera* Reed (*forma typica*, M. U.)
  ,, cf. *megastoma* De Kon. (M. U.)
  ,, cf. *gigantea* Waag. & Pichl. (M.)
  ,, cf. *kolwæ* Stuck,
  ,, *discreta* Reed,
Thamniscus dubius Schloth.? (M.)
Goniocladia indica Waag. & Pichl. (M.)
Pinnatopora sp.,
Acanthocladia sp.,
Streblotrypa birmanica Reed,
  ,, *bassleri* Reed,
Rhombopora circumcincta Reed,
  ,, *virgula* Reed,
Rhabdomeson shanense Reed,
Dybowskiella (*Fistulipora*) *servata* Reed,
  ,, (*Fistulipora*) aff. *carbonaria* Ulr.,
Hexagonella lævigata Waag. & Wentzel. (M.)
Geinitzella cf. *crassa* (Lonsd.) (M.)
Tabulipora sp.,

Actinozoa—

Sinophyllum orientale (Stanley Smith) (at first described as *Lophophyllum orientale*; differs in only trivial details from *S. pendulum* (Grabau) found in the Loping (Middle Permian) formation of China; almost identical with a form from the Permian of the Donetz basin described by Jakowlew and to "*Lophophyllum proliferum*" (McChesney).
Michelinia dieneri Reed.

Crinoidea—

Cyathocrinus virgalensis Waag. (M.)

U.=Species found in the Upper Productus Limestone.
M.=Species found in the Middle Productus Limestone.
L.=Species found in the Lower Productus Limestone.

Other localities.—The isolated hill of Loi Tang, rising from the plain, is capped by Plateau Limestone probably belonging to the Permian section, and may be entirely built up of this rock[1]. Between Mile 28-3 and Mile 69 on the Government Cart Road, the Permian has been recognised at one locality only, between Miles 36-5 and 37-2, in characteristic fossiliferous limestones and calcareous shales forming a low cliff on the west bank of the Pawn river[2].

In the Wanpong belt, which is covered by the typical '*terra rossa*' earthy limestones and calcareous shales, not unlike the purer varieties of the Permian, have been noted on the left bank of the Nam Teng, and similar beds—probably a continuation—have been recorded further south, containing the remains of brachiopods, corals and foraminifera. This belt has been followed for some fortyfive miles to the south beyond Me-lawn (Me-lun), nearly as far as Mawk-mai. Between Me-lawn and Mawk-mai occur Permian varieties of the formation, in which also are situated the old lead pits of Mawk-mai.

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[1] J. Coggin Brown and V. P. Sondhi. *Rec.*, LXVII, 137 (1933).

[2] Gen Rep. *Rec.*, LXVI 99 (1932).

Permian shales and mudstones are exposed in the belt of Plateau Limestone on the right bank of the Salween river.

Returning westwards, both types of the Plateau Limestone are present in the Hsa-Möng-Hkam (Thamakam) range and its northward and southward extensions. Near Lwe-kaw, limestone conglomerates are to be seen interbedded with ordinary brecciated dolomites and with a red, ferruginous, platy limestone ; the calcareous shales, slabby and dark-coloured limestones and yellowish brown shales, in the vicinity, are also interbedded with the dolomites and, though unfossiliferous, are lithologically identical with certain types of the Permian limestone. The red rocks to the east of Lwe-kaw are believed to be local modifications of Plateau Limestone and not members of an older group. Typical brecciated dolomites occur near Kyong, but the presence of *Fusulina* just to the east of Pindaya (Pangtara), and of *Lyttonia* and clisiophyllid corals near Nyaungkaya proves that the limestones of these localities belong to the Permian section of the Plateau Limestone. When these rocks are unfossiliferous, they are not easily differentiated from the older Mawsön beds. The Permian limestone forms the frontal scarp overlooking the Pindaya valley and contains some sacred caves, near which have been found: *Iranophyllum* sp., *Wentzelella* cf. *timorica* (Gerth) and *Polythecalis* sp.[1] From a locality three-and-a-half miles northeast of Pindaya the following corals have been identified by Dr. Stanley Smith:[2]

Lonsdaleia (*Iranophyllum*) cf. *carcinophylloides* Dougl.,
,, (*Waagenophyllum* (?)) sp.,
,, (*Wentzelella*) cf. *timorica* (Gerth),
Polythecalis sp.,
Michelinia siyangensis Reed (Stanley Smith's *Pleurodictyum siyangense*) (found also in China and Persia),
Hayasakaia sp. (the "*Tetrapora*" of Yabe and Hayasaka).

From two miles northeast of Poila comes the Persian species *Iranophyllum carcinophylloides* Dougl. ; from the vicinity of Alechaung, north of Kunlon, has been collected *Iranophyllum spongifolium* Stanley Smith, associated with crinoidal fragments and some bryozoa including *Fistulipora* cf. *sinensis* Yoh.

A Permian fauna in an excellent state of preservation has recently been discovered by Dr. M. R. Sahni at Loi Pan, in the eastern margin of Lawksawk State ; species of *Productus* (especially common), *Chonetes*, *Orthoceras*, *Pleurotomaria* and *Platyceras* are recorded, as well as several species of anthozoan corals and a goniatite.[3]

RELATIONSHIPS OF THE FAUNAS.

With regard to the faunas found in this division of the Plateau Limestone, that of Kehsi Mansam is characterised by the small size of the species as compared with other regions ; even *Productus cora*, the commonest form, never attains the dimensions it does in the Salt Range, in Russia or in South America.[1] The facies of the Namun fauna, from the published lists of fossils, would appear to be very different from that of Kehsi Mansam, but this difference is exaggerated by the greater difficulty of extracting identifiable specimens of bryozoa at Kehsi Mansam, the result being that bryozoa, which are the most characteristic and abundant types in the Namun collections, appear to be very scanty in those of Kehsi Mansam.[2] .

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[1] *Rec.*, LXIII, 89 (1930).
[2] *Pal. Ind.*, New Ser., Vol. XXX, Mem. 2, p. 2 (1941).
[3] *Rec.*, LXXI, 27 (1936).

The Permian faunas of the Shan States as a whole show close affinities with those of the Salt Range Productus Limestone, and more especially with the Middle and Upper groups thereof, while *Oldhamina* is a peculiar type confined to the Indian and Chinese regions.[3] At the same time, many of the resemblances shown by something like one half of the Burmese fauna to that of the Salt Range, do not amount to actual identity of species. Nearly all the species of *Productus* specifically determinable are identical with either Salt Range or European forms; this being so, the scarcity of large species of the *semireticulatus* group is noticeable. With regard to the Htam Sang fauna, although it includes the typical Permian brachiopod, *Lyttonia nobilis*, as well as other Productus Limestone species; in fact, its composition is less like that of the typical Productus Limestones of the Salt Range than are the faunas from some of the other Burmese localities. Dr. Cowper Reed finds that the common and typical species of *Productus* occurring in the Salt Range are absent from the Htam Sang collections.

Opinion regarding the age of these younger Plateau Limestone faunas is not in every case definite, but although some of the species from the Southern Shan States show affinities with Upper Carboniferous forms, there is little doubt that the faunas in these younger Plateau Limestones all belong to the Permian.[4]

The Namun, Hopong-Möng Pawn and Taung-gyi faunas belong in all probability to the Middle Permian, corresponding, as Middlemiss originally suggested, to the Middle Productus Limestone; those of Kehsi Mansam and Htam Sang may show some indications of belonging to slightly older horizons.

The Permian of Burma shows also a close relationship to the Permian of the central Himalaya, and a striking connection with the Permian faunas of the Ural mountains. The presence of several common species shows that the connection with America, which is indicated by the faunas of preceding periods, was maintained in Permian times. There is also a small number of species agreeing with those described from Timor and Rotti in the Malay Archipelago.

KARENNI STATE.

The Plateau Limestone in Karenni succeeds eastwards the so-called Mawchi beds which may be the equivalents of the Mergui series. There is a markedly unconformable overlap between the two formations, and west of the main boundary line between them, scattered outliers of the Plateau Limestone are to be seen for a distance of twelve miles, at various elevations, lying upon the Mawchi beds.[5]

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[1] C. Diener. *Pal. Ind.*, New Ser., Vol III, Mem. 4, 69 (1911).

[2] T. H. D. La Touche. *Mem.*, XXXIX, Pt. 2, 282 (1913).

[3] Apparently identical with the "*Oldhamia*" of some authors.

[4] F. R. Cowper Reed. *Rec.*, LXVII, 128 (1933).

[5] G. V. Hobson. *Trans. Min. Geol. Inst. Ind.*, Vol. XXXVI, 40-41 (1940).

Both types of the Plateau Limestone are present in the Karenni States. In a small range immediately south of Loi-kaw, and also near Saulon, occur limestones, some of them shaly, with crinoids, corals and brachiopods, ill-preserved but generally resembling those found near Pindaya.

Some fossils collected by Mr. G. V. Hobson from three localities twenty-eight miles west of Loi-kaw prove that the Southern Shan States Permian extends into Karenni. Dr. Cowper Reed reports that they consist of ill-preserved casts and impressions sufficiently determinable to show that the beds are the equivalents of the Middle or possibly the Upper Productus Limestone of the Salt Range (*i.e.*, of the Middle or Upper Permian); among them the following have been provisionally identified :[1]

Fenestella sp.
Camarophoria purdoni Dav.,
Marginifera himalayensis (Dien.),
Hustedia remota Eichw.,
Productus jakowlewi (Tschern.),
Martinia cf. *dispar* Dien. or *triquetra* Gom.,
    ,, (*Ella*) cf. *simensis* Tschern., var. *substricta* Tschern.?
Spiriferina sp.
Spirifer (*Spiriferella*) cf. *salteri*,
Spirifer lyra ?

A *Spirifer* found loose three miles south of Mawchi probably belongs to an earlier horizon (Upper Carboniferous) and is not unlike *S. schellwieni* Tschern. from the Schwagerina Limestone of the Urals.[2]

YUNNAN

The Lower Carboniferous (Dinantian), the Middle Carboniferous (Moscovian) and the Upper Carboniferous (Uralian) are present in Yunnan, Tonkin, Laos and Annam. In Tonkin-Annam and Laos, the Lower Carboniferous possesses a fauna remarkably like that of the Viséan in Europe.[3] The same may be said of the whole of the Lower Carboniferous in southern China.[4] The following forms from Ta-shih-wo, about forty miles east of Teng-yueh, have been identified by Cowper Reed who in his classification makes no attempt to separate the Moscovian from the Upper Carboniferous, and assigns the fauna to the Lower Carboniferous, used in a broad sense.[5]

Foraminifera—
    Nodosaria sp.

Spongida—
    Reniera sp.

Actinozoa—
    Syringopora intermixta Reed,
    Campophyllum cf. *caninoides* Sibly,
    Caninia aff. *nikitini* Stuck,
        ,, aff. *lonsdalei* Keys,

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[1] Private communication.
[2] Dr. Cowper Reed ; private communication.
[3] H. Mansuy. *Bull. Serv., geol. Indo-Chine*, VI, Fasc. VI, 72-85 (1919).
[4] Yabe and Hayasaka. "Palæontology of S. China", Tokyo Geogr. Soc. Chapt. 6, 194-204 (1920).
[5] *Pal. Ind.*, N. S., Vol. X, Mem. 1, 24 (1927).

Cyathophyllum fraternum Reed,
,, *sororium* Reed,
,, (*Fischerina* ?) *insolitum* Reed,
,, ,, *solitarium* Reed,
Clisiophyllum (*Rhodophyllum* ?) *elusum* Reed,
Koninckophyllum (*Histiophyllum* ?) *occultum* Reed.

Crinoidea—
Poteriocrinus sp.

Bryozoa—
Fenestella aff. *laxa* Phill.,
Rhombopora cf. *bigemmis* Keys.,
Glauconome [*Pinnatopora*] aff. *bipinnata* Phill.

Brachiopoda—
Orthis (*Rhipidomella*) *michelinii* L'Ev.,
,, (*Schizophoria*) cf. *resupinata* Mart.,
Orthothetes (*Schellwienella*) *crenistria* (Phill.),
Leptœna analoga Phill.,
Productus yunnanensis Loczy,
,, (*Striatifera*) *hemisphericus* Sow. var.,
,, cf. *cora* D'Orb. var. *kok-dscharensis* Gröber,
,, *costatus* Sow.,
,, *longispinus* Sow.,
,, *muricatus* Phill., *var. paucispinosa* Reed,
,, (*Buxtonia*) *scabriculus* Mart., var. *impersonata* Reed
,, (*Dictyoclostus*) "*semireticulatus*" Mart.,
Chonetes papilionacea Phill.,
,, cf. *crassistria* McCoy.
Spirifer bisulcatus Sow., var. *trigonalis* Mart.,
,, ,, , var. *kleini* Fischer,
,, *duplicicosta* Phill. var.,
,, *tornacensis* de Kon. var.,
,, aff. *calcaratus* McCoy,
Spiriferina (*Spiriferellina*) *cristata* Schloth. ?.

Gastropoda—
Loxonema sp.

Trilobita—
Phillipsia spinifera Reed.

Dr. Cowper Reed remarks that most of the Carboniferous fossils from the caves of Wo-shih-wo near Yung-Chang Fu ("Young-tschang-fu"), described by Loczy were, probably, collected from the same bed as that which yielded the above fauna.[1] Loczy, however, admitting that the brachiopods indicated a Lower Carboniferous age, regarded the foraminifera as partly Lower Carboniferous and partly Middle or Upper Carboniferous, and ultimately referred the beds to the "Permo-Carboniferous" (Artinskian). A few specimens of the above fauna were obtained in the vicinity at Sow-wa-shu.[2] On the route from Talu to Wei-sha the following forms were found, the majority of the specimens being ostracods.[3]

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[1] "Beschr. Geol. Beob. u. d. Result. d. Reise d. Grafen Bela Szechenyi in Ostasien 1877-80", 123-130, 202, 203.

[2] F. R. Cowper Reed. *Pal. Ind.*, New Ser., Vol. X, Mem. 1, 61 (1927).

[3] *Ibid.*, p. 68.

Actinozoa—

Syringopora taluensis Reed.

Brachiopoda—

Martinia glaber (Mart.), var. *yunnanensis* Reed.

Crustacea—

Leperditia viator Reed,
,, *subquadrata* Reed,
,, *subœqualis* Reed,
Bairdia cf. *mucronata* Reuss.,
,, cf. *elongata* (Munst.).

Pisces—

Helodus sp.

Cowper Reed refers also to the Lower Carboniferous bed at Ho-shuj-tang to the east of Yunnan Fu, from which have been collected :[1]

Foraminifera—

Textularia sp.,
Bigenerina cf. *elegans* Möll.,
Trochammina sp.

Actinozoa—

Chœtetes radians Fischer.,
Arachnolasma aff. *sinense* Y. & H.
Koninckophyllum (*Histiophyllum* ?) sp.

Gastropoda—

Bellerophon and *Euomphalus*.

A few exposures of the Dinantian occur in the Yang-tze valley, north of Yunan Fo.

The Uralian at Tzu-men-lu, around Yunnan Fu has yielded the two foraminifera :[2]

Neoschwagerina craticulifera (Schwager),
Fusulina cf. *montipara* Ehrenb.

The presence of *Neoschwagerina* and *Fusulina* in the following assemblage from near Pu-erh-Fu, in southwest Yunnan, which appears to consist only of foraminifera and sponge spicules suggests a Uralian fauna : [3]

Foraminifera—

Endothyra sp.,
Valvulina sp.,
Bigenerina sp.,
Fusulina sp.,
Climacammina sp. ?
Trochammina sp. ?
Neoschwagerina sp.

Spongida—

Geodites sp.

The Moscovian or Middle Carboniferous attains an exceptional development of at least 1,200 metres in eastern Yunnan. Great thicknesses of limestone, distinguished by its variety of foraminiferal remains, were also laid down in Uralian, Artinskian and Middle Permian times, during a slow subsidence. This was followed by an emergence of the land and vigorous denudation which removed the limestones more or less completely according to local circumstances.[4]

From the localities of Eul-kai and Tang-chi come faunas which may include Upper Carboniferous forms, but which are in the main Lower Permian (Artinskian) ; they include :

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[1] *Pal. Ind.*, N. S., Vol. X, Mem. 1, P. 76, *Rec.*, XLIV, 106 (1914).

[2] J. Coggin Brown. *Rec.*, XLIV, 109 (1914) ; *Pal. Ind.*, New Ser., Vol. X, Mem. 1. 85 (1927).

[3] J. Coggin Brown. *Pal. Ind.*, New Ser., Vol. X, Mem. 1, 86 (1927)

[4] J. Coggin Brown. *Mem.*, XLVII, 55 (1920).

Foraminifera—
Fusulina sp.
Endothyra sp.

Spongida—
Cœloctadia (?) *tangchiensis* Reed,
Sollasia dussaulti Mansuy.
Reniera sp.

Bryozoa—
Arœopora ramosa Wagg. & Wentz.

Actinozoa—
Campophyllum vigilans Reed,

Brachiopoda—
Streptorhynchus aff. *pelargonatus* Schloth.
Athyris (*Composita*) *eulkaiensis* Mansuy,
,, ,, *tangchiensis* Reed,
,, ,, cf. *subtilita* Hall,
Orthis (*Rhipidomella*) aff. *pecosi* Marc.,
Spirigerella subtriangularis Reed,

Gastropoda—
Euomphalus (*Phymatifer*) aff. *khmerianus* Mansuy,
Pleurotomaria (*Wortheniopsis*) *eulkaiensis* Reed,
Zygopleura parvituberculata Reed,
Bellerophon (*Bucania*) aff. *kattaensis* Waag.

Scaphopoda—
Dentalium sp.

From Ta-li-shao comes a "Permo-Carboniferous" (Artinskian) fauna, which Dr. Cowper Reed has determined as follows:

Actinozoa—
Michelinia yunnanensis Reed,
Plerophyllum aff. *timorense* Gerth,
Tachylasma cf. *cha* Grabau,
Dibunophyllum (*Verbeekiella*) aff. *australe* Beyr.,

Crinoidea—
Poteriocrinus cf. *maschatensis* Roman,

Bryozoa—
Fenestella assumpta Reed,
,, *clusa* Reed,
Thamniscus orientalis Reed,

Brachiopoda—
Derbyia grandis Waag.,
Productus cf. *hemisphœrium* Kut.,
,, cf. *plano-hemisphœrium* Netsch.,
,, aff. *horridus* Sow.,
,, (*Linoproductus*) simensis *Tschern.*,
,, ,, cf. *cancriniformis* Tschern.,
,, (*Waagenoconcha*) cf. *abichi* Waag.,
Marginifera semigratiosa Reed,
concrescens Reed,

Marginifera cf. *clarkei* Tschern.,
Strophalosia proxima Reed,
Aulosteges poyangensis Keys.,
Chonetes pseudovariolata Nik., var. *yunnanensis* Reed,
  ,, cf. *geinitziana* Waag.,
  ,, aff. *transitionis* Krot.,
  ,, (?) *molengraaffi* Broili,
Athyris (*Cleiothyridina*) *roissyana* Keys.,
Spirigerella derbyi Waag.,
Spirifer (*Neospirifer*) *fasciger* Keys.,
  ,, ,, aff. *moosakhailensis* Dav.,
  ,, (*Spiriferella*) *rajah* Salt., var.
  ,, *peregrinus* Reed, and var.,
  ,, cf. *tibetanus* Dien.,
  ,, cf. *strangwaysi* de Vern.,
Syringothyris lydekkeri Dien.,
Martiniopsis talishaœnsis Reed,
Martinia cf. *semiplana* Waag.,
  ,, *bellistriata* Reed,
Reticularia sublineata Reed,
  ,, cf. *waageni* Loczy,
Rhynchopora emerita Reed,
  ,, cf. *nikitini* Tschern. (probably *R. variabilis* Stuck.),
  ,, (?) aff. *wynnei* Waag.,

Lamellibranchiata—

Aviculopecten mcCoyi Meek & Hayd., var.
  ,, aff. *katwahiensis* Waag.,
  ,, *hiemalis* Salt., var *alta* Reed,
Streblopteria cf. *deprati* Mansuy,
Palæolima scabrosa Reed,
Modiola yunnanensis Reed,
Parallelodon cf. *multistriatus* Girty,
  ,, cf. *subtilistriatus* Wanner.

Gastropoda—

Bellerophon sp.

Plantae—

Neuropteris cf. *flexuosa* Sternb.,
Calamites sp.

Seven other localities have yielded small faunas of Carboniferous or Lower Permian age. Among the forms determined are the new species: *Fenestella sinensis* Reed, *F. yabei* Reed *Amphipora asiatica* Reed, and *Chætetes thomsoni* Reed.

In western Yunnan, the fossiliferous Permian limestones are always found in close association with the older, metamorphosed limestones, which they usually appear to overlie unconformably. With their associated contemporaneous volcanic rocks they occupy much of the valleys of the Salween and Mekong as well as the Yang-tze valley north of Ta-li Fu. In contrast to the scree-covered hill-tops and steep cañons of the older section of the Plateau Limestone, the younger builds wider valleys and gentler slopes, through the soil of which their smooth isolated outcrops protrude. The commoner types of the latter are massive and compact, exhibiting shell fragments and foraminifera in thin sections. Individual bands, however, are never very thick and are usually separated from each other by calcareous shales or rarely by more arenaceous deposits.[1] The Fusulina limestones in the neighbourhood of Pu-erh-Fu, in southwest Yunnan, form a line of fantastic peaks.[2]

Volcanic activity was very prevalent during the deposition of these beds, among which are commonly found beds of ash and tuff intercalated with andesitic, doleritic and basaltic flows; in some localities, volcanic beds form the greater part of the succession. The same igneous rocks characterise the Permian of eastern Yunnan, but attain their maximum development in the central portion of the province, especially towards the north, in the valley of the Yang-tze Kiang.[3] North of this river, to the northeast of Erh Hai, Coggin Brown records fossiliferous "Permo-Carboniferous" limestones, and volcanic beds of great thickness, consisting of flows, tuffs and ash beds intercalated with bands of shale and grit; some of the andesites are amygdular. Coggin Brown remarks that the beds seem to be associated rather with the Permian period than with the Carboniferous. In much of eastern Yunnan it has been found possible to separate the Carboniferous from the Permian and to divide the former into upper, middle and lower divisions, though Cowper Reed has thrown some doubt upon the advisability of separating off a middle division from the upper.

In the immediate neighbourhood of Yunnan Fu the following succession has been made out:[4]

4. Upper Permian, with *Neoschwagerina douvillei.*

3. Lower Permian, with *Neoschwagerina craticulifera*, *Fusulina brevicula*, and *F. japonica.*

2. Middle and Upper Uralian; porphyrites, etc.

1. Lower Uralian—or passage beds from Moscovian to Uralian—with *Fusulina* aff. *krotowi.*

One of the most important Permian occurrences in Yunnan is that of Ta-li-shao, in the southwestern part of the province, only some seventeen miles east of the Salween river and situated in the Mekong valley to the southeast of Erh Hai. Many of the species collected from this locality are identical with or closely allied to those occurring in the Middle and Upper Productus Limestone of the Salt Range. That these beds were deposited under shallow water conditions seems indicated by the presence, in a more shaly bed of the same locality, of fragments of the fern, *Neuropteris* cf. *flexuosa* Sternb., and a doubtful fragment of a calamite.[5]

INDO-CHINA.

Productus limestones are very widespread in Tonkin and the Laos, and occur also in Cambodia. A complete series of the rocks exists in central Laos, extending in the form of a long band eastwards as far as the coast of Annam, and westwards to the vicinity of the Nam Sane, a tributary of the Mekong. The limestones often build vast *massifs* of a karstic character with strange topographic forms. They are often very fossiliferous and have yielded brachiopod faunas of same size which have been described by M. H. Mansuy. The brachiopods from the Permian of Cambodia are said to show great affinities with those of the Salt Range. Based on a study of the fusulinids, the Productus limestones of northern Indo-China have been subdivided into twelve horizons which include the Upper Moscovian and the whole of the Uralian and Permian.[6] In some areas, the limestones are replaced laterally, either wholly or in part, by detrital formations, in others by two great series of eruptive rocks—porphyrites and rhyolites. Omitting cases where they are not in their original position, the Productus limestones either rest on the eroded surfaces of Devonian, Dinantian or basal Moscovian formations or, where the succession is complete, pass progressively through from the Moscovian to the Permian, terminating nearly everywhere in a surface of erosion on which sandstones of Triassic age lie. In one locality, however, passage beds to the shaly Trias are believed to exist, containing, in addition to brachiopods and an ammonite with Permian affinities, a species of *Ophiceras*, a genus unknown before the Lower Trias'[7]

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[1] J. Coggin Brown. *Rec.*, XLVII, 228 (1916).

[2] J. Coggin Brown. *Rec.*, XLIV, 95 (1914); *Ibid.*, LIV, 319 (1922).

[3] J. Coggin Brown. *Rec.*, LIV, 74 (1922).

[4] E. Saurin. *C. R. Acad. Sci., Paris*, CXCVII, 174 (1933).

[5] F. R. Cowper Reed. *Pal. Ind.*, New Ser., Vol. X, Mem. 1, 106 (1927).

[6] See the well-known monographs of H. Douvillé, J. Depnat, Mlle Colani, F. Patte, M. Gubler and J. Fromaget.

[7] See *Bull. Serv. Geol. Indo-China*, XIX, Fasc. I, 17 (1931).

II. MOULMEIN LIMESTONE.

THATON AND AMHERST DISTRICTS.

As early as 1856 a fauna consisting of "corals, gastropods, brachiopods, and crustacea" is recorded as having been found in a series of sandstones and overlying grey shaly beds in Tenasserim, and was thought to be of Lower Carboniferous age.[1] Additional fossils from Zwe-ka-pin ("Zwah-ga-byin"), a limestone hill with some well-known guano caves, situated in the Thaton district near Pa-an, some forty miles north of Moulmein, and popularly known as the "Duke of York's Nose", were pronounced to be of the age of the Carboniferous Limestone of Europe. According to Dr. T. Oldham's classification, the limestone series was considered to be younger than the sandstones and shales, but both were apparently included in the "Moulmein system". Unfortunately all these fossils became mislaid. From a welter of somewhat contradictory information the following facts emerge.

The western parts of Thaton are occupied by a series of sandstones and shales in places somewhat metamorphosed, which have been traced from Martaban northwards for over fifty miles, their continuity being broken for a mile or two by the intrusion of the Kalamataung granite *massif*; for considerable distances, pegmatites and quartz veins, originating in the granite, have penetrated the sedimentaries.[2] In sections at Martaban railway station, some of the shales are seen to be highly carbonaceous and contain plant remains too fragmentary for identification, bivalves, casts of what appear to be the brachiopod *Orbiculoidea*,[3] and wings of insects belonging probably to a Palæozoic representative of the *Orthoptera*. Two of the bivalves have been identified by Mr. J. Weir as *Palæanodonta okensis* (Amalitsky), a form which occurs in the Permian marl and sandstones of Nzhjni Novgorod, and *P. subcastor* (Amalitsky) which is found on all the horizons of the Permian marl and sandstones of eastern Russia;[4] both these species occur also at Graaff Reinet in South Africa in the Lower Beaufort, a subdivision assigned to the uppermost Permian by Du Toit.[5] The genus, not found outside the Carboniferous and Permian, belongs to Dawson's family "*Naiadites*" which is confined to fluviatile and brackish-water formations. The marls containing *Palaeanodonta* and other brackish-water molluscs, from the headwaters of the Dwina river, are also assigned to the Upper Permian, and are associated with sandstone lenticles with skeletons of *Pareiasaurus*, *Dicynodon* and other reptiles, as well as impressions of *Callipteris*, *Glossopteris* and *Gangamopteris*. The Lower Beauforts have also yielded the same two genera of reptile and specimens of *Schizoneura* and *Glossopteris*. There is good reason, therefore, for classifying the Martaban sandstones and shales as uppermost Permian, or possibly lowermost Trias.

Across the estuary of the Salween and near Moulmein, limestones crop on which are probably the same as those forming the "Duke of York's Nose" and

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[1] Gen. Rep. *Rec.*, XXVI, 96 (1893); W. Theobald *Mem.*, X, 326 (1873).

[2] Gen. Rep. *Rec.*, LX, 83 (1927).

[3] Requires confirmation.

[4] One of these fossils, probably one of the *Palæanodonta*, is said to have been collected from the adjacent Moulmein Limestone *Rec.*, LIV, 54 (1922), but this is in all probability a mistake.

[5] J. W. Gregory. *Geol. Mag.*, LX, 153 (1923); W. Amalitsky, *Q. J. G. S.*, LI, 347-348 (1895)

Zwe-ka-pin where a subsequent search resulted in the discovery of the fossils already referred to, which never seem to have been fully examined but which included species of *Productus*.[1] In this limestone occur the old sea-caves which have added to the renown of the picturesque town of Moulmein. There are some five groups of these caves, the best known and most accessible being the " Farm Caves ", some ten miles from the town, on the Ataran river; these are situated in isolated hills rising abruptly from the alluvial plain and are full of stalactites and stalagmites. The Moulmein caves are filled with relics of their ancient use as Buddhist temples, but are visited now largely on account of the vast number of bats whose flight from the entrances, when viewed from a distance, resembles a cloud of smoke.

The Taung-nyo range in the Amherst district is a continuation of a ridge in Thaton, stretching S.S.E.' wards from Moulmein with a general strike of N.N.W.-S.S.E. The hills are composed of an unfossiliferous series of sandstones, quartzites, shales and slates, with a dip towards the east of 45° in the north, sinking to 25° in the south.[2] East of the hills is a forest-covered plain revealing nothing but lateritic clay and rubble with a bed-rock of laterite, and river alluvium; further to the east rise the precipitous hills of crystalline Moulmein Limestone. The Taung-nyo beds have been referred to the Mergui series, and this reference is probably correct. Contacts between them and the Moulmein Limestone are somewhat obscure, but the latter is described by Leicester as definitely overlying the former, and isolated outliers of the limestone are to be seen lying on the slopes of the Taung-nyo range; whether there is any considerable unconformity between the two formations has not yet been made clear, but in two or three cases there is distinct discordance in dip between the one and the other.[3] The contacts in some places appear to be faults. In one case the limestone is sheared and slickensided, and has evidently yielded to recent slipping, as proved by the fact that stalactites in a small cave therein are seen hanging at an angle of 35° from the vertical; whether, however, this movement was tectonic in origin or due to earthquake or land-slip is not certain. In another case the limestone and the older series appear to have been folded up together, both being crushed and contorted.

In the opinion of Dr. Coggin Brown the Martaban sandstones and shales will eventually be proved to overlie the limestones of Moulmein, and the evidence so far available favours this provisional conclusion. On this assumption there would appear to be three formations distinguishable in this part of Lower Burma :

3. Martaban beds.
2. Moulmein Limestone.
1. Taung-nyo beds (? Mergui series).

The Martaban beds being definitely Upper Permian, if not a little later, the Moulmein Limestone might correspond to some other portion of the Permian, equivalent to some part of the Permian sequence found in northern Burma and to the limestones of probably similar age in Siam, and might well include Upper Carboniferous horizons.[4] Theobald seems to have correlated the two, for he speaks of cyclopean masses of Moulmein Limestone in the Salween and Ataran valleys, and of large tracts of what he calls by the same name in Karenni, traversed by granite and elvan dykes[1] ; La Touche favours the same deduction. The Taung-nyo beds, whether or not the equivalent of the Mergui series, would thus have to be Carboniferous or older, and, if Mr. Leicester is correct in his supposition that there was no great lapse of time between the deposition of the uppermost Taung-nyo shales and that of the limestone, the age of the Taung-nyo beds need not be older than Carboniferous.[2]

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[1] Gen. Rep. *Rec.*, LIV, 54 (1922).
[2] Gen. Rep. *Rec.*, LX, 91 (1927).
[3] *Rec.*, LXIII, 95 (1930).
[4] Bertil Högbom. *Bull. Geol. Inst. Univ. Upsala*, XII, 65-127 (1913); *Rec.*, LV, 282 (1923).

In the broad valleys between the ranges of older rocks in Amherst, there are extensive developments of Moulmein Limestone, cropping out either as expanses of rock protruding a few feet from the soil, or as the lofty, vertical-sided, castellated and pinnacled hills distinctive of this formation.[3] The limestone is mostly, massive but sometimes shows bedding and interstratification with calcareous shales. The galena and cerussite deposits of the Pagah range in Amherst, as well as the lead and copper ores of the Yunzalin valley in the Salween district, are said to occur in rocks similar to the Moulmein Limestone.

SALWEEN DISTRICT.

Around the upper part of the Yunzalin valley in the neighbourhood of Papun, in the Salween district, there is a rugged, more thickly afforested, southern continuation of the Shan plateau, on which outliers of crystalline limestone form bare, precipitous, and tufa-covered slopes.[4] These limestones are said to be intermittently continuous southwards, by way of the Bilin river, with the limestone on the Salween, north of Moulmein, known as the Duke of York's Nose. They are described as blue, unfossiliferous, brecciated limestones lying unconformably upon slates and quartzites believed to belong to the Chaung Magyi series. With their characteristic fissures, swallow-holes and dry valleys, they form, in their typical development, two high plateau-like outliers which according to Dr. Clegg, lie in a valley of Chaung Magyi rocks, and have precipitous eastern boundaries. The vegetation on them is scanty compared with that on the supposed Chaung Magyis. A stream of some volume issues from a cave at the southern end of the more northerly outlier. There are in addition a few smaller outliers, to some of which (west of Sakan) lead ores are reported to occur. The valley of the Bilin river is flanked by massive limestone.

TAVOY DISTRICT.

The Moulmein Limestone has not been recognized with certainty in the Tavoy district. Doubtful occurrences include some limestones occurring 1,500—2,000 feet above the Great Tenasserim river, limestones uncovered in Kanbauk alluvial tin workings, where they probably overlie the Merguis, and a limestone near Pagaye on the Pauktaing Chaung a few miles E.N.E. of Tavoy town.[5] Crystalline limestones also overlie the Mergui series in a branch of the Kamaungthwe Chaung, a tributary which joins the Tenasserim river opposite Myitta.[6]

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[1] W. Theobald. *Mem.*, X, 326 (1873).

[2] *Rec.*, LXIII, 94 (1930).

[3] A. M. Heron, *Rec.*, LIII, 37 (1921).

[4] E. L. G. Clegg. *Rec.*, LX, 293 (1927).

[5] *Mem.*, XLIV, 184 (1923).

[6] *Rec.*, 72, 58, 60 (1937).

MERGUI DISTRICT.

There are many scattered outcrops of the Moulmein Limestone in the district of Mergui, forming ridges and hills with precipitous sides, rugged and bare of vegetation, and surrounded by alluvium.[1] The rock is characterized by stalactite-bearing caves, some of them of large size, on the floors of which are thick deposits of bat excrement, collected and used at one time in the manufacture of saltpetre. The limestone islands of the Mergui archipelago are inhabited by small swifts whose edible nests of gelatinous saliva used to fetch their weight in silver from the Chinese.

The best known occurrences of the Moulmein Limestone are some small outliers some five miles from the Siamese border in the latitude of Bokpyin, forming precipitous hills above the Klong Thampra, a tributary of the Lenya, one of them being Khao Thampra or Thampra hill. There is a chain of such limestone outcrops northwards along the Ngawun Chaung and across the Tenasserim river to the well-known hills of Kyauktaung and Tharabwin. There is another chain of outcrops farther east, and another group to the west occupies some of the islands such as the Marble Isles east of Domel Island, the small islets to the west of Tavoy Island and, in the south, the Turret Islands with their precipitous limestone cliffs rising sheer from the sea just off the coast in the latitude of Pulo Bada (Sir William James Island), and St. Matthew's Island opposite Victoria Point.[2]

The isolation of the Moulmein Limestone outcrops in alluvium-filled valleys has made it difficult to establish their relationship to the Mergui rocks ; in spite of the lack of junction sections, however, the general opinion is that the Merguis are stratigraphically overlain by the limestone.[3]

The Moulmein limestone of the Mergui district is generally crystalline and coarse-grained, some of the crystals attaining a width of ¼ or even ½ inch. Two analyses show very little magnesia and, in one case, as much as 13·4 per cent of insoluble residue. The rock is described as a tough, compact, fossiliferous limestone, from which it is very difficult to extract the fossils. Thirty or forty years after the earliest discovery, fossils were obtained by Mr. P. N. Bose from a dark, partially silicified limestone near Tharabwin, thought to be probably of the same age as the limestone at Zwe-ka-pin in Thaton ; the following are the identifications made :[4]

Foraminifera—

Schwagerina oldhami Noet.

Actinozoa—

Lonsdaleia (*Wentzetella*) *salinaria* Waag. & Wentz.,
Lithostrotion n. sp.,
Aræopora cf. *ramosa* Waag. & Wentz.

Bryozoa—

Polypora cf. *biarmica* Keyserl.

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[1] S. S. Rama Rau. *Mem.*, LV (1930).

[2] *Rec.*, LIX, 73 (1926).

[3] J. Coggin Brown and A. M. Heron. *Mem.*, XLIV, 180 (1923).

[4] *Rec.*, XXVI, 97 (1893).

Brachiopoda—
- *Productus* cf. *sumatrensis* F. Roemer.,
- *Athyris* sp.,
- *Spirifer* sp.

Gastropoda—
- *Bellerophon* sp.,
- *Pleurotomaria* aff. *durga* Waag.,
- *Murchisonia* sp.

Lonsdaleia salinaria is a characteristic form in the Middle Productus Limestone of the Salt Range. The genus *Schwagerina* does not occur in the Salt Range, but is very common in the Carboniferous Limestone of Sumatra, and is also found in the Uralian horizons, Nos. 5-8, of the succession in Northern Indo-China.[1] Noetling remarks that, so far as conclusions can be drawn from such a limited assemblage, the chief interest lies in the association of Indian (Salt Range) forms with forms from Sumatra ; the scanty fauna was in fact looked upon as a link between these two regions. There is, however, a still closer resemblance between this Moulmein Limestone fauna and the one found in Chitral and allotted by Dr. Cowper Reed with some degree of confidence to the uppermost or *Schwagerina* stage of the Uralian ; this Chitral fauna includes the genera, *Schwagerina*, *Bellerophon*, *Polypora* and the coral, *Lonsdaleia* (*Wentzelella*) *salinaria*. Such a comparison would bring this particular horizon of the Moulmein Limestone down to the topmost Carboniferous, *i.e.*, just below the "Permo-Carboniferous" as understood by Russian stratigraphers.

Relationships of the Moulmein Limestone.—Our knowledge of the Moulmein Limestone and its relationships is at presen very incomplete, but certain facts are suggestive. What the precise relationship is between the Permian section of the Plateau Limestone and the basal Triassic horizons recently discovered in North Hsenwi, further work may shew, but the fact remains that, while comparatively thinly developed in the Northern Shan States, the Permian type of the Plateau Limestone is definitely thicker in the Southern Shan States. Further south still the Calcitic Moulmein Limestone, is the only one recognised, and may well include Lower Permian and Upper Carboniferous horizons. The dolomitic Devonian section of the Plateau Limestone, *per contra*, is enormously thick in the Northern Shan States, but has not been recorded south of Karenni. There is, so far, no evidence to show that the Devonian is represented at all in the Moulmein Limestone. Further discoveries are necessary before it can be concluded that the Devonian section dies out southward in Karenni or the Salween district—perhaps transgressing into Siam—while the higher section covering the Permian and perhaps some of the Carboniferous increases compensatively to form the Moulmein Limestone of Tenasserim, but such a conclusion would seem to be at least an approximation to the truth. In spite of the fact that in only one locality (Mawchi) has a single restrictedly Carboniferous fossil—and that an uncertain determination—been so far found in the Plateau Limestone of north Burma, it would be hard to believe that the limestone sequence of these regions does not include part at least of the Carboniferous.

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[1] Noetling states with *Schwagerina oldhami* is closely related to *S. verbeeki* Gein. ; the latter, now known as *Verbeekina verbeeki* is a Permian form found in certain horizons of the Productus limestones of Indo-China.

Further south, in various parts of Malaya, there is a thick sequence including some 5,000 feet of limestone which is in many ways reminiscent of the Plateau Limestone of Burma and, like it, appears to straddle more than one geological system. In Kelantan, some associated shales have yielded at late Carboniferous flora. In Perlis, a Uralian fauna, with abundant *Fusulina*, has been obtained from the lower division of the formation in which are occasional thin, impure limestone bands. At Lubok Sukum, a horizon in the limestone has yielded an assemblage including *Xenodiscus* and *Dentalium herculea* and believed to be of Permian age. In Kuantan, a Viséan fauna (Lower Carbonifeous) has been collected, and from a locality across the Siamese border, not far from Perlis, an assemblage of much the same age has been described by Dr. Cowper Reed.[1] The magnesium carbonate content of the limestone in Malaya is distributed irregularly ranging from one per cent. to that of dolomite. Carbonaceous varieties are recorded, but in some places the limestone is a particularly pure carbonate rock. In places the limestone has been altered by intrusions of granite. There is evidence that the Malayan formation, which appears to be largely Carboniferous, becomes less calcareous in a southerly direction, a state of affairs in consonance with the view that along these longitudes the shores of Gondwanaland lay to the south.[2]

A similar formation of great thickness and of great diversity, including fossiliferous limestones is described from Sumatra by Professor H. A. Brouwer, who notes that it may include Permian, Carboniferous and even older Palæozoic rocks. The richest fossil collections come from the island of Timor and belong mostly to the Permian, the affinities of which are with the Salt Range, the Urals, Sicily, and the Alps. In spite of a certain independence in the faunal development of the Timor Permian, it has enough in common to indicate that the Tethys geosyncline reached from the Mediterranean to the East Indies as early as Permian times.[3]

III. MERGUI SERIES.

Stratigraphical Position.—The older rock systems of Burma have been studied in the northern and southern, but not so much in the central parts of the province. The correlation between north and south, therefore, is of a provisional nature and may require modification when the intermediate region has been more thoroughly surveyed.

The southern half of Burma comprises from south to north, Mergui, Tavoy, Amhrest, Thaton, Salween, the eastern hilly parts of Toungoo and Yamethin, and Karenni, and ends indefinitely in the Southern Shan States. It is convenient to regard this tract, which includes in addition to the political division of Tenasserim the independent State of Karenni and the Yanethin district of the Mandalay division as a geological province, some 700 miles in length characterised throughout by the presence of a biotite boss granite forming the cores of the ranges of the Burma-Malayan mountain system. Tenasserim and Malaysia further south together form a strip of country carrying the most important tin deposits in the world.

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[1] *Geol. Mag.*, Vol. LVII, 113-120, 172-178 (1920).

[2] J. B. Scrivenor, "The Geology of Malaya", 53-61 (1931).

[3] H. A. Brouwer, "The Geology of the Netherlands East Indies", 17 (1925).

The mountain ranges of the Southern Shan States coalesce in Karenni where there are elevations of over 5,000 feet, but further south maintain a marked individuality. In these more southerly regions of Salween, Thaton, Amherst, Tavoy and Mergui, most of the drainage is approximately N.-S. The granite of the ranges and islands has been intruded into great thicknesses of argillaceous strata with subordinate limestones, quartzites and volcanic detritus, to which the name of the " Mergui series " has been given. The general facies of these rocks was at first described as suggestive of the Dharwar system and they have been coloured as the equivalents thereof on the latest 32-miles geological map. As a whole, however, they show far less metamorphism than this ancient system of the Peninsula, and have nothing whatever in common with the supposed Dharwars of Mogok and the frontier ranges of Bhamoor, to go a little farther afield, with the supposed Dharwarian Ta-li series of Yunnan.

The Merguis are unfossiliferous, and there are lithological resemblances between some of the more metamorphosed varieties and certain members of the Chaung Magyi series of the Northern Shan States, but Coggin Brown points out that such similarities may be an accidental result of the violent and prolonged mountain-building activities in which Tenasserim has shared, and of the soaking which its rocks have endured in the post-Palæozoic granite magmas. The equivalence of the Merguis and Chaung Magyis, however, is a possibility which cannot yet be definitely discarded and is favoured by several observers, the latest of whom is Mr. G. V. Hobson who suggests that the Chaung Magyis may be a non-calcareous facies of the Merguis.[1] The correlation of these two series might seem to derive some confirmation from the fact that the most southerly exposures of rocks assigned to the Chaung Magyi series—*viz.*, those in the Salween district—lie to the south of and in the line of strike of the most northerly outcrops of rocks referred to the Merguis in Bawlake ; resemblances are strengthened—perhaps fortuitously—by the fact that in both localities these ancient sediments underlie the same thick limestone formation and are intruded by a boss of granite.

As a whole, however, there is little in common between the Chaung Magyis and the Merguis. As remarked by Dr. Coggin Brown, for none of the rock series in any way comparable to the Mergui in neighbouring countries a pre-Cambrian age is preferred by observers best qualified to express an opinion. Wallace Lee, for example, is of opinion that his "Metamorphic series" of northern Siam is rather more likely to be a highly metamorphic phase of the Palæozoic beds on the flank of the granite intrusion than pre-Palæozoic sediments turned up or faulted up in connection with that intrusion.[2] Mr. J. B. Scrivenor is not completely satisfied with the claim by some geologists that the Moulmein Limestone lies unconformably upon the Merguis. Whether this is so or not, he suggests that the Merguis may correspond either to the Trias of Malaysia or to the sediments at the base of the Carboniferous, so clearly exposed in the Langkawi Islands and Perlis ; of the two alternatives he prefers the latter, since the Merguis contain no beds of chert.[3] On the other hand, the irregular penetration of the Trias of Malaysia by the granite is said to be very reminiscent of the relationship between the Merguis and the same granite in Tenasserim. In both Malaysia and the Dutch East Indies Dr. Brouwer recognises no stratified rocks older than the Carboniferous and suggests that a large part of the " Old Schists " may be Palæozoic rocks made prematurely old by the great mountain-building activity which affected the area subsequent to their deposition.[1] The Javanese development of such rocks is only local, but they are referred to the Cretaceous. In Indo-China, little work has been done on the crystalline rocks but even here Palæozoic ages have been suggested for certain of the schists. Finally, there is the evidence regarding their age afforded by the volcanic activity which characterised the Mergui period. One of the most striking features of the Merguis is the great development of pyroclastic and effusive volcanic rocks, such as the fine agglomerates of Tavoy, or the coarser agglomerates, the tuffs, rhyolites and other types of the Mergui district. Such an assemblage is strongly recalled by descriptions of the various members of the Pahang Volcanie series of Malaya. This series marks a period of volcanic activity beginning at least in the late Carboniferous and lasting until the Trias[2]; it corresponds closely, in fact, with the Panjal Volcanic suite of Kashmir. Anything of volcanic or hypabyssal origin older than the granite of this region seems to have been included in the series which is recognised as only a part of the more widely spread, coeval, volcanie effusions of Sumatra and Borneo. In parts of Indo-China, especially in the Upper Laos and northern Annam, rhyolitic effusions are said to have commenced in the " Upper Anthracolithie " (Uralo-Permian) and to have continued into the Triassic periods.[3] Thus, to the northeast, east and south of Tenasserim, vast tracts of these late Palæozoic to early Mesozoic volcanic rocks have been proved to exist, and the suggestion that the volcanic rocks of Mergui, Tavoy and even Thaton, may have some connection therewith, is worth serious consideration. Within the confines of Burma, however, there is no definite evidence bearing upon the age of the Merguis, and the inclusion of those rocks in the present chapter rather than in a much earlier one is a purely provisional procedure made in diference to the tendencies of outside opinion. The wolfram and cassiterite veins which penetrate the Merguis belong to a later chapter in the geological history of Tenasserim. It will be convenient to commence with a description of Tavoy, followed by that of Mergui, and then to return to the districts north of Tavoy.

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[1] *Trans. Min. Geol. Inst. Ind.*, Vol. XXXVI, 65 (1940).

[2] Geol. Rep. on Payap and Maharastra, p. 3 (1923).

[3] " The Geology of Malaya ", 84 (1931).

TAVOY.

Physiography.—The district of Tavoy is a rugged tract, made up almost entirely of mountains with a general trend parallel to the N.N.W.-S.S.E. strike of the rocks, and covered with dense tropical jungle of tall evergreen trees and heavy undergrowth. Not much more than 5 per cent. of the area is, in fact, under cultivation.[4] With the exception of two basins of Tertiary rocks in the interior and the Recent deposits along the coast and in the lower portions of the river valleys, the district is built up of Mergui rocks and granite, the area occupied by the outcrops of granite being not much less than that taken up by the Merguis.

Lithology and Structure.—The Mergui series is an assemblage of highly folded and indurated but little metamorphosed sedimentary rocks, which have been extensively intruded by large and small bosses of granite. All the main valleys are occupied by Mergui beds, often in quite narrow strips, with high granite land on either side. It is essentially a formation of hardened and crushed argillaceous deposits, agglomerates and silicified tuffs, with greatly subordinate quartzites, limestones and conglomerates, and is characterised by monotonous uniformity of type over large areas and over great distances measured across the strike. The folding is probably of an isoclinal nature but, owing to the uniformity of rock type and to the inaccessibility and jungly nature of the country, it has not been possible to elucidate the folds in detail. Locally the strike may vary between N.-S. and N.W.-S.E., but the usual trend is N.N.W.-S.S.E. The dip is irregular and, when seen, always high, usually from 60° to vertical. It seems probable that the series is repeated several times in closely pressed folds in any extensive E.-W. section. In such a country faulting is difficult to recognize, but some of the larger mines show numerous small strike faults in both the sedimentaries and the granite. As a result of the luxuriant vegetation and the excessive rainfall, decomposition of the rocks has penetrated to an unusual depth.

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[1] " The Geology of the Netherland East Indies ", pp. 10-12 (1925).

[2] J.B. Scrivenor. " The Geology of Malaya ", p. 84.

[3] C. Jacob. " Géologié et Mines de la France d'Cutre-Mer", 406 (1932).

[4] J. Coggin Brown and A. M. Heron. *Mem.*, XLIV, 167 (1932).

Argillaceous Members.—According to Coggin Brown and Heron, the term argillite is the most suitable one for the bulk of the argillaceous rocks, which are too obscurely stratified to be called shales and show insufficiently developed cleavage to be called slates. These sediments are hard, fine-grained, blue-grey to black in colour, and affected by very close, splintery and irregular jointing, which causes the rocks to split into small angular fragments. Carbonaceous zones have been noted in the argillites, carrying finely divided graphite ; these varieties do not weather to the customary reddish brown lithomarge yielded by the normal argillites, but retain their black colour. A dried sample of a schistose variety of one of these graphitic rocks yielded a percentage of 2·9 of carbon.[1] Close to the granite and pegmatite intrusions, the argillaceous rocks have become to a large extent phyllites and in places even mica schists, with white pyroxene and garnet developed near the contact. Other common contact minerals are andalusite, sillimanite and pyrite. Such typical examples of the effects of thermal metamorphism are, as we shall see, to be matched in Mergui, and are paralleled by the changes suffered by the Triassic shales of Malaya ; the latter are described by Scrivenor as having developed near the granite boundary secondary minerals such as biotite, tourmaline, sillimanite and andalusite, and as having been indurated, in some cases to a rock as compact as chert, breaking in many directions independently of the bedding planes.[2] Whatever the respective ages of the invaded rocks may be, the granite of Tenasserim is probably identical with that of Malaya. The most frequent contact effect, according to Brown and Heron, is a compact and very tough quartzite produced probably by the fusion and recrystallization of the silica of the argillite fortified perhaps with silica derived from the granite during its consolidation; this quartzite often extends for yards from the granite and is a common site for waterfalls.[3]

Pyroclastic Deposits.—Next in importance to the argillites are the fine agglomerates or graywackes which are more especially developed in the southern vicinity of Tavoy town. They can be seen exposed at intervals in the gorge of the Great Tenasserim river where it breaks across some of the ranges. When fresh, these rocks are dark grey, almost black, weathering to an ashy or brown colour. They are built up of a structureless jumble of small angular fragments of quartz, slate, fine quartzite, felspar, etc., of an average size less than that of a grain of wheat but occasionally reaching that of a hazel nut, with very few rounded pieces of granite about three inches in diameter, all set in a fine matrix identical with the material of the argillites. Incidentally, this early pre-Mergui granite has not been found *in situ*. These extremely hard and tough rocks, unaltered except for induration, with neither stratification nor cleavage, represent the finer ejectamenta of paroxysmal eruptions which were the source of the coarse agglomerates of indubitable volcanic origin found in the islands of the Mergui archipelago. Amongst them are broad bands of ordinary argillites with an incipient cleavage parallel to the general strike. The graywackes, being harder than the normal argillites, give rise to cascades and rapids when lying athwart streams, and are typical components of the more elevated tracts of the Mergui series.

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[1] A. W. G. Bleeck. *Rec.*, XLIII, 53 (1913).
[2] " The Geology of Malaya ", 69 (1931).
[3] *Mem.*, XLIV, 181 (1923).

Arenaceous Beds.—Interbedded with the normal argillites are infrequent sandy modifications in the form of impure quartzites. Purer quartzites are to be seen in places, traversed by veinlets of finer quartz; these are fine-grained, unstratified, irregularly jointed rocks, which under the microscope show a mosaic of quartz clouded with aluminous material. The quartzites, as usual, form bold and rugged ridges. It is doubtful whether any true conglomerates occur in the Merguis of the district.

Limestones.—Some, at any rate, of the limestone bands of this district appear to belong to the Mergui series. This rock, sometimes massive but more usually thin-bedded, is for the most part impure and blackish or red in colour, but white saccharoidal varieties full of irregular knots and streaks of ferruginous and clayey material are known.

MERGUI.

Physiography.—The district of Mergui is, geographically and geologically, a southerly continuation of the country of the Tavoy district and includes an extensive archipelago of islands. The ranges and rocks have the general N.N.W.-S.S.E. strike, veering sometimes to N.-S. Geological detail is largely obscured by dense jungle and a thick mantle of soil, both the results of an annual rainfall averaging about 184 inches.

Structure.—The sequence is in all probability repeated by folding and anticlines and synclines are claimed to have been recognised.[1] The dip is most frequently steep, but is sometimes gentle, and folding is in most cases as compressed as it is in Tavoy.

Lithological Character.—The Mergui rocks of the Mergui district are similar in character to those of Tavoy but differ therefrom in small but interesting ways. The coarser forms of pyroclastic deposits are locally more plentiful and in fact mark the sites of actual volcanic foci; the series generally is more arenaceous; conglomerates are comparatively frequent and moderately coarse; lithological types are described as being more definite, with less gradation from one to the other, indicating a slightly more successful sorting action.

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[1] S. S. Rama Rau. *Mem.*, LV, 13 (1930).

Argillaceous Types.—The predominant members are phyllites and argillites, dark grey in colour and weathering to buff or brownish red clays of the succession. The argillites in many parts of the district are fine-grained and finely laminated, breaking easily along the bedding planes and approaching micaceous slates. They have been converted into hard slates and hornstones by the intrusive granite—for instance, along the contact of the Tagu granite boss[1]; in many cases chlorite has been formed, and in one place the result of intrusion has been the production of brown biotite, magnetite and garnet. The phyllites in places carry many lenticular patches of graphitic material,[2] and the shales are sometimes carbonaceous. There are many grades of calcareous shales with varying quantities of lime.

Conglomerates.—The pebbles of the conglomerates usually range up to three inches in diameter, and consist mainly of quartz and felspar; one of them has been recorded as being composed of a biotitic and well-foliated granite, confirming other indications of a pre-Mergui granite. The argillites on the east coast of Lampi Island are interbedded with conglomerates, the pebbles of which consist chiefly of biotite-hornblende granite, quartz and quartzite; and range from an inch to a foot in diameter; some argillaceous pebbles and pebbles of jasper show flat surfaces. The indications are, in fact, that the pebbles of the locality travelled no great distance from their source. Some of the conglomerates on the mainland are described as passing gradually into slates.

Arenaceous Beds.—Quartzites are somewhat more prominent than they are in Tavoy, and give rise to similar falls and rapids. Sandstones, more or less indurated, occur, and there are many grades of calcareous varieties with varying quantities of lime.

Limestones.—Impure blackish or red limestones are to be seen, and crystalline forms have been noted.

Pyroclastic Rocks.—The most interesting rocks of the district are the tuffs and agglomerates. On the west coast of Elphinstone Island and on the small islets adjacent thereto occur volcanic agglomerates of the types usually found in and around volcanic necks, including fragments of pumice, devitrified glass, sedimentary rock, felspar porphyry, cellular pumiceous rhyolite sometimes showing sphærulitic structure, and white tuffs full of bombs and lapilli. Associated with these agglomerates, which form high conical peaks on Elphinstone, are dykes and small bosses of hypabyssal rocks in the form of porphyritic microgranite and granite consisting of large orthoclase phenocrysts in a granophyric groundmass.[3] The west coast of this island shows a great series of rhyolites and porphyries; the central portion is occupied by coarse, hornblende-biotite granite, differing from the type on the mainland in having hornblende in addition to biotite. On Maingay's Island to the northeast, there is a great development of volcanic agglomerate, forming similar conical peaks and composed of quartz, felspar and biotite fragments, with chips of glass and quartzite, evidently the product of the paroxysmal eruption of a magma corresponding in composition to granite or rhyolite. These two localities probably coincide with two of the principal foci of eruptions which distributed their debris so widely through the Mergui series of Tavoy and Mergui.[1] The northern shore of King Island and the neighbouring Iron Island perhaps mark the site of another. At the former are seen numerous sills of porphyritic granite and granite porphyry, showing marked fluidal structure ; these hypabyssal rocks are thought to belong to the same volcanic period as the agglomerates. Ashy rocks have been noted on Singu Island off the mouth of the Lenya river. On the mainland east of this estuary is another band of tough, indurated, volcanic tuffs, with angular fragments of felspar and sub-angular pebbles of slate of varying size. These rhyolitic flows and tuffs remind one forcibly of the Malani suite of Rajputana and of similar rocks elsewhere in the Lower Vindhyan, but such resemblances between areas 2,000 miles apart are probably of no material significance.

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[1] Gen. Rep. *Rec.*, LIV, 51 (1922).
[2] Gen. Rep. *Rec.*, LIII, 20 (1921).
[3] Gen. Rep. *Rec.*, LV, 33 (1923).

Schistose types, Pegmatites and Veins.—Near Talobusa, the shales of the Mergui series appear to have been intimately intruded by granite, just as they have been in Green Island and on the Amherst coast, and metamorphosed to hornblende and biotite schists. Hybrid products thus produced have shared in the crustal movements which affected the Merguis, and are traversed by pegmatite veins branching irregularly in varying directions, while quartz veins of still later age, orientated N.E.-S.W., have cut across the pegmatites.

AMHERST.

Physiography.—The general geology of the Tavoy district continues northward into the district of Amherst. This is largely a plain country but there are three continuous ranges of hills extending through it in a general N.N.W.-S.S.E. direction ; these converge towards the south and join the mountain mass where Amherst, Tavoy and Siam meet. The westernmost range—the Taung-nyo—the continuation of a range in Thaton to the north, separates the coastal plain from the Ataran valley. The middle range forms the divide between the Ataran and Haungtharaw streams, while the eastern, the loftiest of the three, is the Dawna range which lies between the Haungtharaw and the Thaungyin river, the latter forming the boundary separating Burma from Siam.

The two outermost ranges, and in addition much of Bilugyun Island, are made up of an assemblage of highly folded and indurated sediments, very similar to the Mergui series in Tavoy and Mergui, with which they are no doubt continuous, and like them extensively intruded by bosses of granite, some of them of considerable size.[2] The dark shales, exposed along the coast and on Green Island, have been metamorphosed to mica schists and mica-hornblende schists by the granite which has become contaminated by absorption of the invaded sediments. In the broad valleys of Amherst, between the ridges of these granite-intruded sediments are extensive developments of the Moulmein Limestone.[1] The Dawna range is composed of coarse, banded gneisses and schists with gneissose granites—types foreign to the Tenasserim geological province. The hills between the Dawna range and the Siamese frontier are composed probably to a large extent of Mesozoic strata, but the Mergui series, according to Cotter, is possibly represented by a small outcrop of hornblendic quartz schist on the bank of the Mepale river, 2½ miles southwest of Tawok-ywa.[2]

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[1] Gen. Rep. *Rec.*, LIV, 52 (1922).

[2] Gen. Rep. *Rec.*, LIII, 37 (1921) ; *Ibid* LVI, 95 (1924) ; *Ibid.* LXII, 99 (1929).

West of the Taung-nyo range is a band of alluvium, broken only by the Amherst hills and the laterite deposits surrounding them. The Amherst hills are lithologically the same as the Taung-nyo range, and the rocks thereof have a general, westerly dip. These rocks, which in places are considerably veined with quartz, are said to pass through metamorphosed sandstones and schists into the injection gneisses, granulites and phyllites of the coast, where *lit-par-lit* intrusion of granïte has been active.[3]

Lithological Character.—The Mergui rocks of the Amherst district, with an average strike N.N.W.-S.S.E. and a steep and often vertical dip, are catalogued as fine black slates and argillites, with subordinate quartzitic sandstones, grits and impure limestones. Metamorphism is of a local rather than regional character and is probably due in the main to the granite intrusions. The predominant rocks are hard, dark slates, roughly cleaved and often quartzitic; these slates of which there are great thicknesses are fine, very uniform, distinctly fissile rocks, black or dark-blue in colour, not so hard as the uncleaved argillites of the Tavoy Merguis but otherwise very similar.[4] There are in these slates no signs of stratification by differences in texture and colour to show whether the cleavage is induced or coincident with original lamination. Dr. Iyer refers to some of the argillaceous rocks as shales, black and graphitic, or red, with bedding often discernible.[5] Other types recorded are graywacke, arkose and phyllitic mica schist. Associated with the slates are quartzites which in places are somewhat argillaceous. The limestones, which according to Heron are distinct from the Moulmein Limestone are little more than non-fissile calcareous slates, and are traversed by many fine irregular cracks filled with calcite. Two outcrops of sandstone conglomerate with well-rounded pebbles have been recorded as occurring in the Ye valley. East of

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[1] Mr. Leicester found no definite proof in this area of an unconformity between the Moulmein Limestone and the rocks of the Taung-nyo range. For the latter he proposed the provisonal name of "Taungnyo series", but their equivalence to the Merguis is practically certain. His conclusion was that there was probably no great time interval between the deposition of the "Taungnyo" rocks and that of the Moulmein Limestone. He suggests, in fact, that the former, and therefore also the Merguis, may occupy a position well up in the Palaeozoic sequence. Folding, faulting and cleavage have obscured the junction between the two formations and the want of discordance in one or two cases may not necessarily infer a continuous sequence. Neverthless, proof of unconformity is lacking as much as proof of conformity. It is to be noted that a conclusion similar to that of Leicester was arrived at by Vinayak Rao with regard to the Merguis and Moulmein Limestone in the Nagwan Chaung, a tributary of the Little Tenasserim river. Here the Merguis are described as underlying the Moulmein limestone and passing up gradually into them; Sethu Rama Rau, however, who saw these and other exposures seems to have formed the opinion that the two formations are in general unconformable (*Rec.*, LV, 32, (1923); *Mem.*, LV, 18 (1930)).

[2] *Rec.*, LV, 275 (1923); *Ibid.* LVI, 96 (1924).

[3] Leicester. *Rec.*, LX, 91 (1927).

[4] Gen. Rep. *Rec.*, LIII, 38 (1921).

[5] *Rec.*, 72, 68 (1937).

Lamaing, the Mergui series is made up for the most part of banded gneiss or tuff, felspathic sandstone, graywacke and agglomerate.

Contact with the granite.—Southwards, the sandstones and shales of the Taung-nyo rocks terminate against the granite boss which sweeps inland from the coast; near the granite boundary they are largely replaced by quartzites and slates strongly resembling the rocks which occupy the southern part of the district and are continuous with the Merguis of Tavoy.[1] Mr. Leicester remarks that the granite masses appear to have contributed a considerable amount of silica to the argillaceous rocks where the latter come into contact with the igneous rock.[2]

THATON.

A narrow belt of quartzitic sandstones, argillites and grits, a few miles east of the Thaton-Martaban railway, has been referred to the Mergui series; as in Tavoy and Mergui, these beds carry wolfram-bearing and tin-bearing veins. In the Thaton-Martaban hills west of the railway, there is an outcrop of slates, containing a small stibnite-bearing quartz vein, and presumably belonging to the Merguis.[3]

KARENNI.

A series of fine-grained sedimentary rocks, comprising clay slates, very fine sandstones and grits, calcareous mudstones and limestones, is described by Mr. G. V. Hobson as occurring in the Mawchi area of Bawlake, one of the Karenni States. These rocks have been given provisional name of the " Mawchi series ", " pending a possible correlation with the Mergui series " of the more southerly parts of Burma.[4] Eastwards, the Mawchi beds are succeeded by the Plateau Limestone with a markedly unconformable overlap, the newer formation lying upon the older in scattered outliers for distances up to twelve miles west of the main limestone scarp and at varying elevations. Westwards, the Mawchi sediments are replaced by a metamorphic complex, the change from the one to other being in most places a gradual transition. The bands of limestone, one of which has played a prominent part in the formation of the Mawchi cassiterite and wolfram ore-body, are lenticular and have an orientation generally parallel to the strike of the rest of the rocks. In the mine area, a boss of biotite granite has invaded and metamorphosed the Mawchi beds.

The general strike varies from N.N.W.-S.S.E., to N.W.-S.E., and the structure is one of tightly-packed folds, some of which are probably isoclinal. The dip in most cases is high, but may fluctuate rapidly; in the more central part of the area, relatively gentle folding on a small scale is occasionally to be seen. Strike faulting is observable here and there.

The metamorphic complex, which here forms a wide belt along the western margin of the Shan plateau, is regarded by Hobson as a highly altered and intruded facies of the normal Mawchi series; it is made up of gneisses, epidiorites, hornblende schists and mica schists, invaded by wide expanses of granitic intrusions.

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[1] Gen. Rep. *Rec.*, LXIII, 94 (1930).

[2] *Rec.*, LXII, 100 (1929).

[3] *Rec.*, LVI, 100 (1924).

[4] *Trans. Min. Geol. Inst. Ind.*, Vol. XXXVI, 40-41 (1940).

The granite of the Mawchi mine is presumably the Tavoy Granite of late Mesozoic or early Tertiary age. It has given rise to a narrow metamorphic aureole in the invaded Mawchi beds, with the formation of marble, quartzite, indurated slate and spotted grit. Secondary biotite, calcite and actinolite have been developed, but the thermal alteration is generally of a low order.

With regard to the age of the Mawchi beds, we have the choice of the following alternatives :—

(i) that the Chaung Magyis of north Burma and the Merguis of the south are more or less equivalent in spite of lithological differences, the exposures in Yamethin, Bawlake, Salween, Toungoo and Thaton, all belonging to one and the same formation ;

(ii) that while the Chaung Magyis may be pre-Cambrian, the Merguis are much nearer in age to the Plateau Limestone. In this case we may (*a*) assign the Yamethin and Salween exposures to the Chaung Magyis and the Bawlake and Thaton exposures to the Merguis, a scheme which has been provisionally adopted in this work, or (*b*) refer the Yamethin beds, the "Mawchis" of Bawlake and the beds in Salween, all of them either to the Merguis or to the Chaung Magyis.

The Yamethin beds, which were assumed by Dr. Cotter to be Chaung Magyis, resemble the Merguis to the extent of having thin bands of limestone, and are evidently regarded by Mr. Hobson as the equivalents of the Bawlake beds which he thinks will eventually prove to be members of the Mergui series. It may be mentioned that Mr. Hobson, although he has mapped separately the limestone bands among the Mawchi rocks of Bawlake, is evidently satisfied that they belong to the Mawchi sequence and are not folded-up outliers of the Plateau Limestone ; outliers of the latter have been recognised as such in the Bawlake area. A similar statement applies to the limestone bands in the beds in Yamethin assumed by Dr. Cotter to be Chaung Magyis. In attempting to estimate the age of theMawchi beds, too much importance must not be attached to their association with a granite whose latest phases appear to have been responsible for a cassiterite-wolfram mineralisation. Both the granite and the mineralisation are much younger than either the Chaung Magyi or Mergui deposits and, while they are characteristically associated with the latter, their penetration of the former is possible and cannot be precluded, especially in the debatable country between the main exposures of the two sedimentary formations.

DEVONIAN PALÆOGEOGRAPHY.

Various movements at the end of the Silurian period divided the marine area of the globe into several more or less distinct basins. The disturbances which in Europe produced the Caledonian Mountains and North Atlantic land area caused a large part of northern Asia to become dry land. Along the southern fringe of the Caledonian land-mass accumulated the Old Red Sandstone deposits. A large sea stretched across central Europe and central Asia, and may have been connected with the sea which covered parts of South Africa, South America and the United States.

The few localities in Asia in which a marine Lower Devonian fauna has been recognised comprise Turkistan, Afghanistan, East Ferghana, Chitral, the Northern Shan States of Burma, the Altai Mountains and the Salair Mountains on the Southern frontier of Siberia. In the Northern Shan States, the Himalaya, the Ural region and Eastern Ferghana are to be found relics of sedimentation continuous from the close of Silurian to the beginning of Devonian times; such continuity can be observed in Great Britain and several other parts of the globe. Throughout China, Lower Devonian occurrences are confined to continental deposits with a few plant remains. Dr. Grabau's map of Lower Devonian geography shows an enormous continent, stretching from the north of Asia to southeastern Asia including the East Indies, and westwards through India to Persia, Arabia and beyond.[1] Two arms of the Boreal sea are drawn stretching southwards into the heart of this great land-mass. The more easterly of these extends from the Gulf of Yenisei to the Salair Mts. The more westerly channel stretches from the north coast of European Russia through the site of the Ural Mountains and thence southeastwards to the border country of Afghanistan, Turkistan and Chitral; a side channel probably connected it with the central European sea and was responsible for the marked Bohemian element in the Lower Devonian faunas of the Urals, East Ferghana and the Hindu Kush. In the Himalaya, no visible sign of a break exists in the continuity of deposition from the beginning of the Muth period (Upper Silurian and the greater part of the Devonian) to the middle of the Carboniferous. The Muth, Tanawal and Jaunsar series of the Lesser Himalaya are all unfossiliferous. If they are of marine origin, they would be regarded as evidence of the slight but widespread sinking which the margin of the Gondwana continental area underwent at this time. If any of these Himalayan sediments are of sub-aerial or fresh-water origin and of Devonian age, they would be regarded as the silts of rivers draining a section of the land-mass northwestwards into the Uralian gulf.

The world-wide marine transgression which took place at the beginning of the Middle Devonian epoch was responsible for the fact that Middle and Upper Devonian sediments are very frequently found superposed unconformably upon pre-Devonian rocks, the Lower Devonian being absent. This marine encroachment initiated a uniformity of conditions which prevailed during the remainder of the Devonian period and gave rise to a more generalised life assemblage over extensive portions of the globe. At the beginning of the Eifelian, this transgression was not sufficient to destroy completely the barrier between the Eurasiatic life province and the province of North and South America. The Ural gulf, *i.e.*, the more westerly of the two extensions from the Boreal sea, seems to have been an exception to the general marine invasion and to have retreated. The more easterly arm, on the other hand, the Tomsk geo-syncline of G. B. Barbour[2] with its Boreal fauna, became prolonged southwards across the western end of Mongolia to join a mediterranean sea which stretched from central and southern Europe through the Bosphorus region, across Asia Minor and Persia, along a re-opened Himalayan geo-syncline to Burma, Yunnan and Indo-China. In the eastern parts of this Tethys sea lived the Padaukpin fauna, the corals and brachiopods of which consist predominantly of types characteristic of the European Eifelian, including the well known *Calceola sandalina*. The fauna of the *Calceola*-shales of western Europe has also been recognised in Armenia and Siberia. Middle Devonian deposits are known to occur in southern China, eastern Yunnan, Tonkin and Annam. In Indo-China they consist for the most part of the Eifelian which is the most widespread stage of the Devonian in that country and shows a colossal development. In eastern Yunnan, the Eifelian and Givetian are both well developed. Species identical with or related to all the Padaukpin corals are found in the Chinese Middle Devonian. The Eifelian of Tomsk, with its *Calceola sandalina*, contains nearly all the European species found in the Padaukpin beds. The small but distinct American element (Chemung) in the Padaukpin fauna is not readily explicable from Dr. Grabau's map,[1] but arrived either *via* the Tethys sea or, as suggested by Du Toit,[2] started from western North America and travelled *via* the western and southern shores of Gondwanaland; the same American element is found in eastern Australia, but not in western Australia or the Himalaya. The greater part of Australia in Devonian times was occupied by land which, according to Sir Edgeworth David, was clothed, probably for the first time in its history, with a living mantle of green. In the middle epoch of this period, this vegetation consisted of closely-packed slender stems and a net work of rhizomes of *Schizopodium*, a plant which was half moss, half alga. "In later Middle Devonian and in Upper Devonian times, representatives of the class of the Lycopodiales had already attained arborescent proportions, the stems of *Lepidodendron australe* being about four inches in diameter and having a length of probably 15 to 20 feet." The Devonian period was one of considerable volcanic activity in the Australian region. In the central Himalaya the poorness of the material of Middle Devonian age prevents a satisfactory analysis of its faunistic characters, but Cowper Reed's recognition of European brachiopods (*e.g.*, *Orthothetes umbraculum*) proves the presence of the same life province in this region. [3]

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[1] "Stratigraphy of China", Vol. I, 145 (1924).

[2] J. W. Gregory, "Structure of Asia", p. 195 (1929).

Further marine invasion took place in the northern hemisphere during the Givetian or upper stage of the Middle Devonian. According to Grabau, the Angaraland of the Asiatic land-mass became split off from "Tibetia" and "Cathaysia"—the latter an ancient land tract including Further India and the East Indies—by the Mongolian geo-syncline which united with the Tomsk channel and the waterway connecting the latter with the Tethys across the Tian Shan. From the Tian Shan channel a subsidiary arm made its way E.N.E'. wards, north of Tibet along the axis of the Kuen Lun geo-syncline. It was not an expansion of this arm, however, but of the end of the Tethys or Himalayan geo-syncline which enlarged the Chinese basin. The Givetian fauna is well developed in China, including eastern Yunnan, eastern Kwang-si and southern Hunan, and appears to be present also in Tonkin; with its type fossil, *Stringocephalus burtini*, it has been recognised in the Tomsk area and the Ural Mountains, as well as in Canada and western Europe. Finally, the water which covered the Ural geo-syncline spread over Russia to form a wide sea. As we have seen, the Padaukpin fauna contains a few Givetian forms, indicating probably that the expansion of the Tethys survived the Eifelian.

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[1] "The Stratigraphy of China", Vol. I, 156 (1924).

[2] "Our Wandering Continents", 66 (1937)

[3] *Rec.*, XL, 30 (1910).

In Du Toit's reconstruction of events, Gondwanaland was in Middle Devonian times surrounded and isolated by the sea which stretched from Australia through Yunnan, Burma and the Himalaya to the Mediterranean region.

In the Frasnian epoch of the Upper Devonian, the Tomsk channel dried up, the Angara land-mass becoming united to what Grabau conveniently calls Tobolskia and Caucasia, but remaining separated from Cathaysia by the persisting Mongolian geo-syncline, as shewn by well-developed Frasnian deposits in the Altai Mountains. The Tian Shan arm became prolonged eastwards across what are now the Nan Shan ranges to unite with the Chinese basin, forming the "Nanshan geo-syncline". The Chinese basin increased in size, for both epochs of the Upper Devonian in China are more widespread than the Middle Devonian. The Frasnian has been recognised in Yunnan, but no undoubted Upper Devonian exists in Indo-China. The Tethys sea still stretched eastwards from the Bosphorus, across Asia Minor the Elburz Mountains of north Persia, the Hindu Kush range of eastern Afghanistan, Eastern Ferghana, Chitral and the western Himalaya. For this reason the Frasnian fauna of Chitral is more closely allied to that of western Europe than to that of the Urals; the fauna of this age in Eastern Ferghana includes several Chitral species. Whether the mediterranean Tethys retained its connection eastwards with the Chinese basin or became separated therefrom by the emergence of the eastern portion of the Himalayan geo-syncline, is not certain, but it is true that neither the Frasnian nor any other typical Upper Devonian fauna has so far been recorded in the eastern Himalaya, and the connection of the Chinese basin and the Wetwin area of north Burma with the Tethys may have been *via* the Nanshan geo-syncline north of Tibet, as shown on Grabau's map. That the Chinese basin was connected with the Boreal region by way of Europe and the Tethys seems proved by the recent discovery of the *Goniatites* (*Manticoceras*) *intumescens* fauna in central Hunan.[1] The home of this "*Intumescens* fauna,"as it is usually called, was the Boreal province, from which it migrated into North America on the one hand and into western Europe on the other. Many of the European species of this fauna are identical with North American forms. In addition the *Intumescens* fauna has been recognised in north Russia and the Urals and, as previously mentioned, has representatives in the Wetwin shales of the Northern Shan States; *Goniatites Manticoceras intumescens* itself is absent from Wetwin, perhaps because of the estuarine tendencies of the fauna. This shallow-water character is in fact perhaps responsible for the contrasts between the Wetwin fauna and the Upper Devonian faunas of Europe and of Asia, with the exception of the Hunan occurrence. It is probable, therefore, that the Wetwin assemblage is not so anomalous as has been supposed, and that it and the Hunan fauna reached southeast Asia from Europe by way ofthe Tethys and either the Nanshan geo-syncline or a re-opened Himalayan geo- syncline. As stated previously, the Upper Devonian fauna of the Chitral and Pamir occurrences are essentially European in facies.

The Ak Baital fossils from the Pamirs are regarded by Grabau as forming a passage fauna between Middle and Upper Devonian, which assembled while the connection with the Boreal region by way of the Tomsk channel remained open.

During the Famennian epoch, the distribution of land and sea remained much the same in Asia as it was in the Frasnian. By this time, great uniformity of conditions had become established over the whole world, and the close of the Devonian period was characterised by many organic forms with a very wide geographical distribution. The principal change in the European area was the contraction of the Ural waterway and the emergence of the Russian platform.

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[1] Y. C. Sun. *Bull. Geol. Soc. China*, XIV (2), 249-252 (1935).

Both stages of the Upper Devonian are well exposed in southern Shen-si and the adjoining parts of southern Kan-su and northern Sze-chuan ; they are, in fact, most typical throughout the Tsing-ling geo-syncline, resting so far as known, disconformably upon the Lower Silurian. They have also been found in the border region of Hunan, Kwang-tung and Kwang-si. The Upper Devonian of Indo-China has a sandy and calcareous facies, indicating an uplift of the sea bottom. The Devonian is wholly absent from northeastern and eastern China.

CHAPTER XX.

THE MARINE FACIES OF THE CARBONIFEROUS AND PERMIAN AND THE EXTRA-PENINSULAR GONDWANA DEPOSITS OF INDIA.

General considerations. Lower Carboniferous : **Kangra and Bashahr, Punjab Himalaya, Kashmir :** Rupshu ; Upper Jhelum valley ; **Afghanistan.** Middle and Upper Carboniferous : **Kangra and Bashahr, Punjab Himalaya, Kashmir :** Rupshu ; Upper Jhelum valley ; Karakoram ; Other parts of Kashmir. Upper Carboniferous and Permian : " Marker " value of the Talchir horizon ; **the Salt Range and its trans-Indus extension :** Classification. **A. Nilawan series :** Talchir stage—Conularia Beds—Speckled Sandstone—Lavender Clay. **B. Productus Limestone series :** Distribution and classification ; Lower Productus Limestone ; Middle Productus Limestone ; Upper Productus Limestone ; Fauna of the series. **The Panjal Volcanic System of Kashmir and other parts :** General distribution and relationships ; **(i) The Agglomeratic Slate ; (ii) The Panjal trap ; (iii) The Stratigraphical limits of the Agglomeratic Slate and the Panjal trap ; (iv) Panjal Intrusives ; (v) Some individual outcrops of the Panjal Volcanics**—Lidar valley—Marbal valley area—Banihal area—Basmai-Kolahoi area—Nagmarg area—Zoji La—Pir Panjal—Shamsh Abari area—Gurais area—Devigarh—Himalaya—Hazara syntaxis—Hazara—Chitral and Gilgit—Kanawar Traps of Mandi—Dalhousie area—Chamba State Garhwal and Tehri Garhwal—Eastern Afghanistan and Russian Turkistan—Central Tibet. **Lower Gondwana occurrences of Kashmir :** Distribution and Stratigraphical position ; Vihi District—Nagmarg area—Pir Panjal—Flora and fauna of the Plant Beds. **Permian marine sequence in the Punjab Himalaya and Eastern Kashmir :** Spiti and Rupshu ; Changchenmo valley ; Karakoram ; The Zewan beds and Productus Shales of central Kashmir. **The Productus Shales in the Great Himalaya of Garhwal and Kumaon. Baluchistan. Rewah State. Infra-Trias of Hazara. " The Great Limestone " of Jammu and Kashmir. Blaini series :** Relationships and subdivision ; Blaini stage ; Blaini stage in Sikkim ; Infra-Krol stage. Krol series ; Distribution and classification ; Krol Sandstone ; Lower Krol Limestone ; Red Shales ; Upper Krol Limestone ; Krol succession in Dehra Dun and Garhwal. **Shali series of the Simla area.** The Deoban Limestone and the Mandhali series ; Deoban Limestone ; Mandhali series. **Exotic Blocks in Garhwal. Kumaon and Ngari Khorsum (Hundes).** Baxa series of Darjeeling and Bhutan. Gondwanas of the Eastern Himalaya : Extent and mode of occurrence : Nepal ; Darjeeling ; Bhutan : Aka Hills ; Dafla Hills ; Lakhimpur district ; Miri Hills ; Abor Hills ; Mishmi country. **Mount Everest area. Chitral. Gilgit and the Pamirs. Central Tibet. Afghanistan :** Fusulina Limestone series ; Khingil series ; Doan series. **Persia. Khyber area.** Palaeogeography of the Lower and Middle Carboniferous epochs.

General considerations.—The Upper Palæozoic and Mesozoic rocks of India are represented in the Peninsula by a great thickness of strata deposited for the most part sub-aerially in river valleys, and known as the Gondwana system. The Extra-peninsular counterparts of these rocks, on the other hand, are very largely of marine origin and, since their age can be more satisfactorily established and they form an important link in the chain of argument by which the age of the Gondwana system is determined, they will stand first for description. Their equivalents in Burma come partly under the head of the Plateau Limestone which has already been described. The Peninsular and Extra-peninsular rocks of this portion of the stratigraphical record, although exhibiting the contrast to be expected between continental and marine deposition, have a basal bed in common and show admixture of one type with the other in places situated on or near the old coast-line which separated the two regions. Such admixture is most common in the Extra-peninsular areas, but one example occurs within the northern margin of the Peninsula in rocks corresponding to the early part of the Gondwana era ; several cases are observable along the Coromandel coast, but these are all of them in rocks laid down towards the end of the Gondwana period, *i.e.*, in Mesozoic times.

Marine Carboniferous rocks are found in the Salt Range, Hazara, Kashmir, the Spiti area of Kangra and Bashahr, the Simla area, Garhwal and Kumaon, the eastern Himalaya and, as we have seen, probably among the Plateau limestones of Burma. In the following table will be found the names of the various local formations which go to make up the stratigraphical section under consideration.

The Gondwana era is, by more or less general assent, considered to have commenced about the beginning of Upper Carboniferous times and to have continued into the early Cretaceous. Such a conclusion is strengthened by evidence from similar deposits in South Africa, Australia and South America. Its upper limit in India has not been categorically defined, but may be taken as the base of the so-called Lameta series. Any fresh-water bed between that horizon and the Upper Carboniferous, especially if plant-bearing, may be conveniently included in the Gondwana system. This, of course, is a purely conventional arrangement. The Lametas and Inter-trappeans, both closely bound up with the Deccan Trap—under the heading of which they are described—are merely continuations of the Gondwana sedimentation, but a line has to be drawn somewhere, otherwise this great fresh-water system would swell to an inordinate thickness and include such deposits as the Pleistocene Cuddalore sandstones and even the more recent Indo-Gangetic alluvium.

West of the Bay of Bengal, the Lower and Middle Carboniferous of India have so far been recognised only in Spiti and Kashmir, but are to be seen in the adjoining countries of Afghanistan and Persia. The Upper Carboniferous is represented in part by a glacial tillite—the basal stage of the Gondwana system—found, not only over a large portion of the Peninsular and Extra-peninsular regions, etc., of India, but also widely distributed in the continents of the southern hemisphere. Its consideration and that of its Permian accompaniments, should preferably form an integral chapter of its own, but certain practical difficulties make it advisable, even at the risk of some unavoidable repetition, to include the Extra-peninsular occurrences of this interesting deposit in one chapter and its Peninsular occurrences in another. The later chapter will include a brief survey of the deposit as a whole, and a still later chapter will refer to its equivalents in other countries. It is proposed, therefore, to begin the present chapter with a description of the Lower and Middle Carboniferous outcrops of the northwest and north, and complete it with a consideration of the Extra-peninsular rocks (excluding those of Burma) corresponding more or less closely to the European Upper Carboniferous and Permian.

	Kangra & Bushahr.		*Kashmir.*		*Salt Range.*		*Hazara.*		*Simla & Chakrata.*	*Garhwal & Kumaon.*	*Eastern Himalaya.*	
Upper Trias.												
Middle Trias.												
Lower Trias.								Krol Series (? Shali Series).	Upper Krol Limestone.			Productus Limestone.
Upper Permian.	Kuling system.	Productus Shales.	Productus Shales.	Great Limestone.	Productus Limestone Series.	Upper Productus Stage.	Infra-Trias.		Red Shales.	Productus Shales.	Baxa Series.	
Middle Permian.		Calcareous Sandstone.	Zewan Series.			Middle Productus Stage.			Lower Krol Limestone.			
Lower Permian.		Sandstone and Conglomerate.	Panjal Volcanics.	Zewan Series.		Lower Productus Stage.			Krol Sandstone (local).		Lower Gondwana including Talchir Boulder Bed.	
Upper Carboniferous.	(*unconformity*).			Gangamopteris beds. Local conglomeratic beds.	Nilawan Series.	(iv) Lavender Clay. (iii) Speckled Sandstone. (ii) Conularia Beds. (i) Talchir Boulder Bed.	Tanakki Conglomerate.	Blaini Series.	Infra-Krol stage. Blaini stage.			
Middle Carboniferous.	Kanawar system.	Po Series.		Fenestella Series.								
Lower Carboniferous.		Lipak Series.	Syringothyris Limestone.									
Devonian.												

LOWER CARBONIFEROUS.

KANGRA AND BASHAHR, PUNJAB HIMALAYA.

In the Spiti valley, where it crosses that northern portion of Bashahr State known as Kanawar (Kanaur), the Muth Quartzite, as we have seen, is overlain by the Lipak series, the lower sub-division of the Kanawar system. The Lipak series consists of a lower portion, representing probably a part at least of the Devonian (see page 662), and an upper group of limestones and quartzites, more than 1,400 feet in thickness, assignable to the Dinantian or Lower Carboniferous. In precipices rising some 4,000 feet above the Lipak river, a small tributary of the Spiti, a fine section is exposed, displaying almost the whole of the Silurian system with the Muth Quartzite, and the Devonian limestone with its coral bands, surmounted by the succession shown below :[1]

Kanawar system.	Po series			Middle Carboniferous.
	Lipak series	Yellow and buff, crystalline limestone, Dark, flaggy, splintery limestone.	500 feet.	Lower Carboniferous
		Limestones with thin bands of soft shale, in both of which fossiliferous horizons occur; the lowest bed a flaggy limestone—the Syringothyris Limestone.	370 ,,	
		White quartzite	25 ,,	
		Hard, dark, crinoidal limestone . .	185 ,,	
		White and grey quartzite, with purple slates and subordinate bands of flaggy limestone.	225 ,,	
		Limestone, weathering yellow and reddish brown.	130 ,,	
			1,435 feet.	
		Dark, splintery limestone with coral bands (Devonian.)	360 feet.	
		Muth Quartzite.		

The two quartzites in the Lipak succession closely resemble lithologically the Muth Quartzite. The limestones, especially the uppermost beds, in the Lipak area and elsewhere, have in many places been converted into pure white gypsum by the action of sulphurous thermal springs found in the neighbourhood. Across the Tibetan frontier bounding Kanawar, the quartzites and accompanying limestones in the higher portion of the Lipak series are greatly altered by contact metamorphism. In parts of Kanawar, the Lipak series, from the top of the Muth Quartzite to the base of the Po series, is said to measure over 2,000 feet.

The middle stage, consisting of 370 feet of limestones and shales, though much crushed and folded, is more or less fossiliferous throughout. From seven horizons in this stage, fossils have been collected in a fair state of preservation, most of the forms found in the lowest horizon—the Syringothyris Limestone—occurring also at higher levels ; the following from the limestones have been identified by Diener and Hayden[2] :

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[1] H. H. Hayden. *Mem.* XXXVI, 37 (1904)

[2] *Pal. Ind.* New Ser. Vol. V. Mem. 2 (1915) ; *Mem.* XXXVI, 38-41 (1912).

Actinozoa—
Chætetes radians Fisch.

Bryozoa—
Polypora sp.

Crinoidea—
Numerous crinoid plates.

Brachiopoda—
Discina or *Orbiculoidea* sp.,
* *Productus* (*Linoproductus*) *cora* d' Orb. (probably including *Pr.* (*L.*) *lineatus* Waag.),
* ,, cf. *punctatus* Mart.,
* ,, cf. *longispinus* Sow.,
* ,, sp. (group of *semireticulatus*),
* ,, cf. *pustulosus* Phill.,
* *Chonetes hardrensis* Phill., var. *kashmiriensis* Lyd.,
,, *lipakensis* Dien.,
* *Derbyia* cf. *senilis* Phill.,
* *Leptæna* cf. *analoga* (Phill.),
* *Syringothyris cuspidata* Mart.,
Spirifer cf. *kashmiriensis* Dav. (*holdhausi* Dien.),[1]
* *Martinia* cf. *glabra* Mart.,
* *Dielasma* cf. *gemmula* de Kon.,
,, *kanauricum* Dien.,
* *Rhynchonella davreuxiana* de Kon. (perhaps a variety of *Rh. pleurodon* Phill.),
* *Camarophoria* cf. *crumena* Mart.,
Reticularia lineata Mart. (possibly equivalent to *Squamularia asiatica*),
Athyris "*royssii*" Lév. (The term "*Athyris royssii*" has been applied to so many variable forms that its individuality is questionable.)

Lamellibranchiata—
Conocardium sp.,
Aviculopecten sp.,

Gastropoda—
Pleurotomaria sp.,
* *Euphemus* cf. *urei* ("*eurii*") Flem.,
Capulus sp. (the "*Platyceras* cf. *carinatum*" of Hayden),

Pteropoda—
Conularia haydeni Dien. (cf. the British *quadrisulcata* Miller),

Trilobita—
Phillipsia aff. *cliffordi* Woodw.,

Pisces—
* *Helodus* cf. *crenulatus* Newb. & Worth,
* ,, cf. *angulatus* Newb. & Worth.

The shales of this stage, excluding the highest, contain the following fossils or casts :—

Brachiopoda—
Discina [?*Orbiculoidea*] sp.,
,, cf. *newberryi* Hall,
* *Lingula mytiloides* Sow.,
Chonetes hardrensis Phill., var. *kashmiriensis* Lyd.,
Syringothyris cuspidata Mart.,
Spirifer sp. (in places very common).
Rhynchonella davreuxiana de Kon. (in places very common),

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[1] Diener notes that *Spirifer* was not identified by him from the Lipak area fossils sent to him ; that genus he identified however, among specimens from Muth and Kuling.

Lamellibranchiata—

Aviculopecten sp.

Gastropoda—

Euomphalus sp. (a small specimen closely resembling *E. hecale* Hall from the Devonian of New York),

Pleurotomaria sp.

Cephalopoda—

Orthoceras sp.

Pisces—

Psammodus sp.

The highest shale contains immense numbers of *Estheria*, some of which have a close resemblance to *E. striata* Muenst.

The presence of *Syringothyris cuspidata*, *Phillipsia* cf. *cliffordi* and *Helodus* cf. *crenulatus*—especially the first of these three fossils points to a Lower Carboniferous age, but this assignment is put beyond any doubt by the fact that 18 of the specifically determinable forms, *i.e.*, three-fourths of the whole (marked above with an asterisk), show close relationships with members of the European and American Lower Carboniferous faunas. Only four new species have been found in the Syringothyris Limestone of Spiti and Kanawar, and its correlation with the Mountain Limestone of Europe rests on satisfactory stratigraphical and palæontological evidence.[1] Its equivalent in Australia is the Burindi series of New South Wales. With the exception of the crinoid limestone none of the other Lipak stages has yielded fossils.

To the west of the area just described, the fossiliferous middle stage of the Lipak series (including the Syringothyris Limestone) has been recognised at Muth and Kuling in the Pin valley. At Muth, about 450 feet of the series are present in the form of siliceous limestone, calcareous sandstone and dark, fossiliferous limestone; since these beds are unconformably overlain by the basal Kuling conglomerate, believed to be of Lower Permian age, it seems likely that the Po series is absent. Near the middle of the section, the limestone contains large numbers of *Syringothyris cuspidata*, *Spirifer holdhausi*, *Dielasma* sp. and *Rhynchonella davreuxiana*, while 50 feet lower down is a band composed almost entirely of the last mentioned brachiopod. Beneath the *Rhynchonella* band, there are only 100 feet of the Lipak series to represent not only the lower part of the Lower Carboniferous but also the Devonian limestone. In the Lipak area, only thirty or forty miles away, the corresponding section measures about 1,000 feet. There is thus a remarkably rapid thinning-out of the Lipak beds from east to west, while the Po series or Middle Carboniferous apparently disappears altogether.

At Kuling, seven miles to the north of Muth, a little farther down the Pin valley, the same limestone sequence is seen, perhaps in a little greater thickness, but otherwise similar to that at Muth. The topmost beds are dark, flaggy limestones which, like the uppermost beds at Muth, are overlain unconformably by the Kuling beds. These flaggy limestones are apparently unfossiliferous, but underlying them is a limestone very similar to the lowest fossiliferous horizon of the middle stage in the Lipak section—the Syringothyris Limestone. The commonest fossils are the brachiopods :—

Productus (*Linoproductus*) *cora* d' Orb.,

,, (*semireticulatus* group),

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[1] C. Diener. *Pal. Ind.*, New Ser., Vol. V., Mem. 2, 135 (1915).

Leptœna analoga (Phill.),
Syringothyris cuspidata Mart.,
Spirifer trigonalis Mart.,
Rhynchonella davreuxiana de Kon.,
Camarophoria cf. *crumena* Mart.,

and with them occur " *Reticularia lineata* Mart.," and *Orthothetes* (or *Derbyia*) sp. Below this fossil band are quartzites and hard limestones, which are thicker than the corresponding beds at Muth, though thinner than those in the Lipak section.

A few miles northwest of Muth, in the Parahio valley, the Lipak series and the greater part of the Muth Quartzite have been cut out by a fault, but reappear further to the northwest, and near the sources of the Spiti river thicken rapidly to a broader outcrop. The total thickness of the Lipak series in this locality, in spite of its large development, is probably less than it is in the type area. The beds are crushed and faulted, but a few of the Lipak horizons can be recognised, including the lowest fossil horizon of the middle stage with large numbers of distorted specimens of *Productus*, *Chonetes* and *Rhynchonella*, and the flaggy limestones near the top of the series.

From a " grey, flaggy limestone northwest of Muth ", Dr. Diener determined the following Lower Carboniferous assemblage: *Syringothyris cuspidata* Mart., *Productus* (*Linoproductus*) *lineatus* Waag., *P.* " *semireticulatus* " Mart., *Derbyia* cf. *senilis* Phill., *Athyris* cf. " *royssii* " Lév., *Spirifer* cf. *strangwagsi* de Vern., *Amboco Elia* aff. *fusiformis* Phill., *Martiniopsis* cf. *subpentagonalis* Waag. *Rhynchonella confinensis* Schellw. and *R.* cf. *wynnei* Waag., (perhaps Reed's *Rhynchopora* (?) *complanata* identified in the Middle Productus Limestone.)[1]

KASHMIR.

Rupshu.—In the district of Rupshu (Rukshu), Kashmir, the Lipak series is most probably represented in the country to the south of the range west of Hanle, by white and dark grey crystalline limestone with interbedded white quartzites; these beds underlie schistose forms of what may be beds of the Po series. Similar beds of calc-schist and crystalline limestone with bands of white quartzite have been observed in smaller thickness on the west side of the Morari Lake (" Tso Marari " or " Tso Moriri ") at its northern end. These limestones and quartzites of Rupshu are underlain by slates and schists which gradually become garnetiferous, then felspathic, and appear to pass down into the so-called " Tso Morari Gneiss ", for the most part a granite intrusion of unknown age but corresponding possibly to the Central Gneiss.

Upper Jhelum Valley.—In the vale of Kashmir above Srinagar, forming part of the pitching anticline which crosses the Lidar valley northeast of Islamabad the Muth Quartzite is succeeded by the Syringothyris Limestone (Lower Carboniferous) except where the latter is unconformably overlapped by the Panjal Volcanic beds. The limestone is overlain by passage beds passing up into the Fenestella Shales (Middle Carboniferous), except where the Agglomeratic Slate or the Panjal Volcanic traps, the local representatives of which belong largely in all probability to the Upper Carboniferous, overlap these shales. In the Kotsu hill the succession is seen to be as follows :—[1]

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[1] *Pal. Ind.* New Ser., Vol. XXIII., Mem. 2, p. 132 (1943).

(Fenestella series and passage beds).

Limestone	100 feet.
Quartzites Thin limestone band Band of trap	300 ,,
Well-bedded, fossiliferous limestone	450 ,,
	850 feet.

(Muth Quartzite).

The two most characteristic species collected from the main limestone are : *Syringothyris cuspidata* Mart. and *Chonetes* aff. *hardrensis* Phill., var. *kashmiriensis* Lyd. Other forms found are : *Productus cora* d' Orb., *P. longispinus* Sow., *P.* "*semireticulatus*" Mart., *P.* cf. *scabriculus* Mart., *Chonetes* aff. *comoides* Sow., *Spirifer* cf. *bisulcatus* Sow., *S.* cf. *cinctus* de Keyser, *Athyris subtilita* (Hall), var. *acutiplicata* Dien., *Orthis* (*Schizophoria*) aff. *resupinata* Mart., species of the genera *Derbyia* and *Rhynchonella*, and a few corals and crinoids.

Southwest of Islamabad, between Budil and the Banihal Pass, Wadia has found a considerable thickness of Lower and younger Carboniferous beds, folded with Lower Cambrian strata in a series of open, normal, northwesterly pitching anticlines and synclines. Unconformably over the Cambrian beds come 3,000 feet of Syringothyris Limestone, with badly preserved *Syringothyris*, and other brachiopods. Succeeding the limestone are 2,000 feet of black shales and quartzites and conglomerates of younger Carboniferous age, containing well preserved *Fenestella*, *Productus*, *Spirifer* and *Pecten*. It is possible that the Lower Carboniferous occurs in other parts of Kashmir also.

AFGHANISTAN.

In northern Afghanistan, the Helmand series fills the gap between the Hajigak and Fusulina limestones and, in the opinion of Hayden, represents presumably the lower and Middle Carboniferous. It consists of an extensive series of slate and quartzite in highly dipping beds exposed along the northwest side of the Paghman range, in the Sang-lakh range throughout the upper reaches of the Helmand, and again the Koh-i-Baba. In places, the slates have been altered by granite intrusions into chiastolite-bearing phyllites and occasionally into well defined schists, between Gardan Diwal on the Helmand and Jaokul, the series includes a limestone which has been converted by the granite magma into calc-schist or a grey saccharoidal marble. On the water parting between the Helmand and Kabul rivers, a dark greenish, compact but coarse conglomerate forms a conspicuous member of the formation.

The slate, schist and quartzite, which make up so much of the crest and south-eastern slopes of the Hindukush, may be a facies of the Helmand series metamorphosed by granite ; the same tentative assignment applies to part of the slate, schist, graphitic schist and quartzite in the hills between Bamian and Saighan[2].

MIDDLE CARBONIFEROUS

KANGRA AND BASHAHR, PUNJAB HIMALAYA.

In the Kanawar area of Bashahr, the uppermost limestones of the Lipak series ara overlain by alternating beds of shale and quartzite, which have been desinated the Po series, owing to their great development in the neighbourhood of the peak of that name. In the Lipak river section, the total thickness of the beds is small, but below Po, on either side of the Spiti river, it is not less than 2,000 feet. In the lower part of the series shales predominate, but towards the top the two types alternate rapidly, the quartzite bands increase in thickness and become more numerous, while the shales become siliceous and gritty and occasionally contain thin pebble beds. The shales are usually black, but in the neighbourhood of the dykes and sheets of amphibolite and dolerite which have been intruded into these rocks they, become reddish, brown and schistose or are converted into hard slates and pyritous and garnetiferous mica schists.[1] The quartzites often resemble the Muth Quartzite, but are, of course, younger. The basic trap intrusions have been mistaken for bedded flow but, if followed for any distance, they are invariably found to cut across the bedding-planes of the sedimentary beds; they belong presumably either to the Panjal trap suite or to the much later Cretaceous-Eocene Dras Volcanics. The Po series is overlain by the basal Kulings, below which there is a stratigraphical gap. Since the Kuling system is now regarded as synonymous with the Permian, the Po series should approximate to the Middle Carboniferous. Neither the Po nor the Lipak series has so far been identified in the Himalaya of Kumaon, the overlying Permian beds here resting on a denuded surface of the Muth Quartzite or, more rarely, on the underlying limestone.

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[1] C. S. Middlemiss. *Rec.* XL, 219 (1910).

[2] H. H. Hayden. *Mem.* XXXIX, 25-26 (1913).

Fossils are very rare in the Po series, but in the Po area have been found at three principal horizons. The lowest of these is to be found on the left bank of the Spiti river, a mile or more above the village of Thabo; here the basal stage of the Po series consists of a band of green shale with poorly preserved plant remains which are of especial interest in that they are members of the oldest known identifiable flora in India. Among them are sterile fronds or frond fragments of what are either true ferns or fern-like seed-bearing plants, one of which has been described by Professors W. Gothan and B. Sahni as very similar to *Sphenopteridium* (?) *furcillatum* Ludw., having at the same time resemblnaces to *S. dissectum* Goepp.; both of these are found in the Lower Carboniferous of Germany. Another frond belongs probably to the sphenopterid *Rhodea*, but a third frond originally compared to the Australian *Rhacopteris inæquilatera* Feist., has been definitely identified by Gothan and Sahni as *Rhacopteris ovata* (McCoy) Walkom., another Australian species. Both *R. inæquilatera* and *R. ovata* are typical fossils in the uppermost of the three stages of the Kuttung series of New South Wales, a formation which, on the authority of Süssmilch and others, represents the Middle Carboniferous. It is interesting to find a member of the well-known *Rhacopteris* flora at the base of the Po series—an horizon which, accepting the above correlation, cannot be older than Middle Carboniferous.[2]

Of the other two principal fossil horizons the lower occurs in a black shale with concretions. The shales in this Po area are everywhere full of concretions which, however, have been found to contain fossils only at this one horizon consisting of two rows of concretions separated from each other by about two feet of shale; the fossils are well preserved, brachiopods on the whole predominating. In the lower row, fossils are rare and consist chiefly of species of *Nautilus*, while the upper contains brachiopoda and bryozoa; this double horizon has yielded the following:—

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[1] H. H. Hayden. *Mem.* XXXVI, 45 (1904).

[2] See W. Gothan & B. Sahni. *Rec.* 72, 202 (1937); also C. Walkom, *Proc. Linn. Soc. New S. Wales*, LIX, 430 (1934), and C. A. Süssmilch, Presidential Address, Melbourne Meeting of the *Australian* and *New Zealand Assoc. for the Advan. of Sci.*, 95 (1935). Sir E. David's Notes to the Geological map of Australia (1932), Table D, opp. p. 58. Gothan and Sahni draw the boundary line higher up and claim a Lower Carboniferous age for the bed.

Bryozoa—

Fenestella sp.

Brachiopoda—

Productus (*Buxtonia*) *scabriculus* Mart.,

,, (*Linoproductus*) *lineatus* Waagen.,

Dielasma sp.,

Athyris (*Cleiothyridina*) cf. *gerardi* Dien. (Species originally known as "*Spirigera gerardi*"

Reticularia lineata Mart. (?*Squamularia asiatica* Chao,).

Spirifer cf. *triangularis* Mart.,

Gastropoda—

Pleurotomaria sp.,

Cephalopoda—

Nautilus sp.,

Orthoceras sp.,

The highest of the three fossil horizons is known as the "Fenestella Shales" and contains immense numbers of bryozoa with a few badly-preserved brachiopods, and includes :

Bryozoa—

Protoretepora ampla Lonsd.,

Fenestella aff. *plebeia* McCoy.

Brachiopoda—

Productus (*Striatifera*) *undatus* Defr.,

,, (*Buxtonia*) *scabriculus* Mart.,

,, *spitiensis* Dien.,

,, *nystianus*, var. *lopingensis* Keys.,

Camarophoria aff. *acuminata* Gemm.

Lamellibranchiata—

Aviculopecten aff. *hiemalis* Salt.,

,, aff. *morahensis* Waag.,

Myalina aff. *recurvirostris* Meek & Worth,

Posidonomya sp.

The supposed identity of several of these fossils with leading species from the Zewan beds of Kashmir, which are regarded as probably of Lower Permian age, was a mistake due to the mixing of forms from the Fenestella Shales with forms from the true Zewan beds.[2] If the base of the Zewan beds corresponds to the conglomerate of Spiti, the survival of the bryozoan, *Protoretepora ampla*, from the Fenestella Shales up to the Zewan beds, through a postulated glacial epoch followed by one of volcanic activity, is not so striking as was at first supposed, and does not involve any unusual stability of this species or its re-immigration at the close of the volcanic period. The presence of a variety of *Productus nystianus* gives the fauna an Upper Carboniferous aspect.

Faulting and disturbance make it difficult to decide as to the relative ages of the two higher of the three principal fossil horizons, but it is thought that they are separated from each other only by a small thickness of rocks ; this surmise is confirmed by the fact that near the head of the Spiti river the Fenestella Shales contain brachiopods (including *Productus scabriculus*) exactly resembling those found in the concretionary band near Po.

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[1] C. Diener. *Pal. Ind.*, Ser. XV, Vol. I, Part. 5, 198-199 (1903).

[2] H. H. Hayden. *Rec.* XL, 262 (1910).

A fourth fossil horizon is to be seen in the Po area, about 300 feet above the Fenestella Shales ; this is a shale band containing fragments of brachiopods and bivalves, but all too badly preserved for determination.

From the manner in which the younger Palæozoic beds thicken again in upper Spiti, it is probable that the Po series will be found further to the north in the upper Chandra valley of Lahaul ; it has been definitely identified in Kashmir.

KASHMIR

Rupshu.—Below the crushed grits and conglomerates of what may be looked upon as the Upper Carboniferous in the Rupshu district of Kashmir, a series of slates and metamorphic schists, occupying country to the east of the Pang-po river, probably represents the Po series of Kanawar and Spiti ; it is underlain by limestones and quartzites which with equal probability belong to the Lipak series.[1] It seems thus possible that the Po series is continuous under the high Mesozoic ranges north of the Spiti river to Rupshu where, however, the rocks have been greatly metamorphosed.

Upper Jhelum valley.—In the pitching anticline crossed by the Lidar river, northeast of Islamabad, the Syringothyris Limestone succession (Lower Carboniferous) is succeeded normally by the Fenestella series, except in places where the latter is overlapped by the younger Panjal traps. Where the anticline pitches, the outcrop of the Fenestella beds swings round in a broad horse-shoe shape, interrupted by a small cross fault. The Fenestella series in its turn is overlain by members of the Agglomeratic Slate, except where the latter are also overlapped by the Panjal traps. Since the Agglomeratic Slate and Panjal traps are here succeeded by beds with Permian fossils, an Upper Carboniferous and Permian age for the local sections of the two former is indicated, and probably a Middle Carboniferous age for the Fenestella series.

In the Jhelum valley, the Fenestella series, the equivalent of the Po series of Kanawar and Spiti, comprises over 2,000 feet of quartzites, in beds varying from a few feet to 100 feet in thickness, with intervening layers of shale which are generally dark in colour and sometimes slightly calcareous.[2] It is in the lower part of the series that these shales are principally developed and carry a rich bryozoan and brachiopod fauna, of which *Fenestella* is a conspicuous member. The lowest beds of all, however, consist of a considerable thickness of unfossiliferous quartzites, sandstones and shales (Middlemiss' "Passage Beds"). The shales and sandy shales of the series possess a rude cleavage and in places approach slates ; they frequently contain pyrite pseudomorphs. Towards the middle of the series, the shales become less conspicuous and, so far as is known, without fossils. Along with the shales, more especially in the upper levels, occur ferruginous sandy beds which sometimes grade into the overlying quartzites. Not far from the uppermost limits of the series, where the beds appear to be passing up into the Agglomeratic Slate, there is a recurrence of a *Fenestella*-bearing horizon, which is separated from the lower by 800-1,000 feet of unfossiliferous strata. Occasional trap intrusions are seen in the rocks. An interesting fact, noted by Wadia, is the prevalence in the upper part of the sequence of black pyroclastic material far below the passage of the beds into the overlying Agglomeratic Slate. This occurrence

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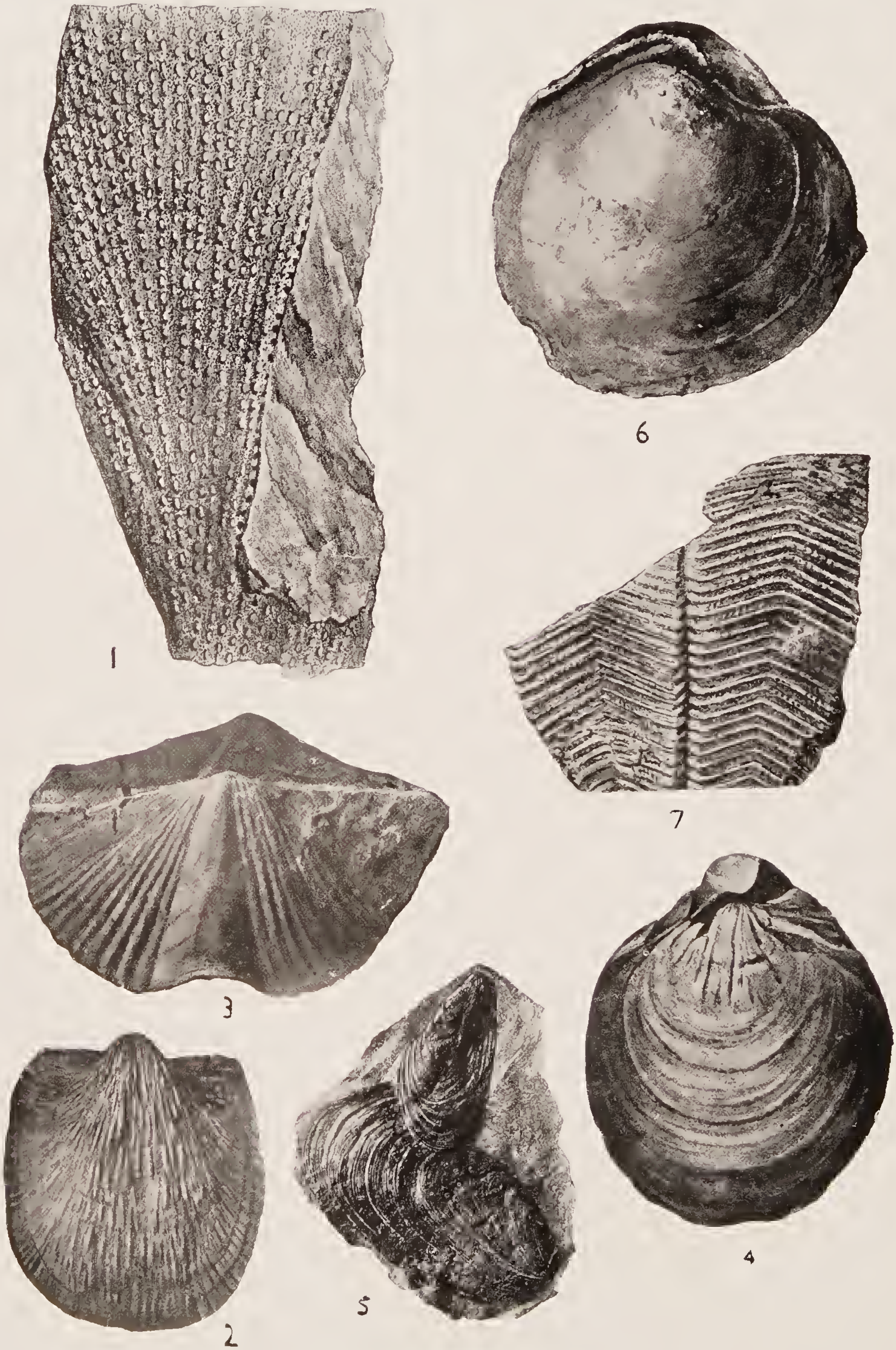
[1] H. H. Hayden. *Mem.* XXXVI, 93 (1904).

[2] C. S. Middlemiss. *Rec.* XL, 225 (1910).



CARBONIFEROUS FAUNA.

1. *Protoretepora ampla* Lonsdale. 2. *Productus spitiensis* Dien. 3. *Syringothyris cuspidata* Mart. 4. *Dielasma lidarense* Dien. 5. *Modiola lidarensis* Dien. 6. *Eurydesma hobartense* (Johnston) var. *rotundata* Reed. 7. *Conularia punjabica* Reed.

G. S. I., Calcutta.

suggests that the commencement of the volcanic period took place long before the end of the Fenestella Shales epoch.

Many of the fossils, especially the brachiopods, are in the form of casts only; the following forms have been collected from three horizons in the series and identified mostly by Dr. Diener :[1]

Bryozoa—
Fenestella aff. *plebeia* McCoy.,
Protoretepora cf. *ampla* Lonsd.

Brachiopoda—
Productus (*Striatifera*) *undatus* Defr.,
,, cf. *cora* d'Orb.,
,, "*semireticulatus*" Mart.,
,, aff. *scabriculus* Mart.,
,, *lidarensis* Dien.,
,, (*Buxtonia*) *spitiensis* Dien.,
,, cf. *humboldti* d'Orb.,
,, *dowhatensis* Dien.,
Aulosteges percostatus Dien.,
Orthotichia sp.,
Derbyia dorsoplana Dien.
Uncinella middlemissi Dien. (found in the Lower Productus Limestone of the Salt Range.)
Syringothyris lydekkeri, (Dien.),
Spirifer trigonalis Mart. var.,
,, cf. *triangularis* Mart. (*? Sp. dieneri* Tschern.).
,, (*Paeckelmannella*) *middlemissi* Dien.,
,, *varuna* Dien.,
Spiriferina sp.,
Camarophoria dowhatensis Dien.,
,, aff. *humbletonensis* Howse.
Uncinulus sp. (probably *Uncinunellina* or *Uncinuloides*),
Dielasma lidarense Dien.,
,, *hastatum* Sow.

Lamellibranchiata—
Modiola lidarensis Dien.,
Rutotia sp.,
Aviculopecten middlemissi Dien.,
,, aff. *kokscharoffi* de Vern.

Pteropoda—
Conularia punjabica Reed (a Salt Range form ; Diener's "*C. tenuistriata* McCoy").

Trilobita—
Phillipsia sp.

Again we find a very large preponderance of brachiopods. The *Protoretepora* is one of the few faunistic elements which connect the series with the younger Zewan beds. *Chonetes*, which plays a somewhat important part in the Syringothyris Limestone fauna, and the genus or sub-genus *Marginifera*, so common in the Zewan beds, have not been found in the Fenestella series. *Conularia Puujabica*, originally described as *C. tenuistriata* McCoy, is a link with the Speckled Sandstone (Upper Carboniferous) of the Salt Range. The fauna maintains a highly individual character; half the species are new and restricted to the group, and there is in fact little faunistic evidence to show what the age of the beds precisely is.

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[1] *Pal. Ind.*, New Ser., Vol. V, Mem. 2, p. 51 (1915). To this assemblage may perhaps be added: *Productus* (*Striatifera*) *mongolicus* Dien., var. *subcircularis* Reed, *Derbyia* cf. *senili* Phill., and *Chonetes barusiensii* Davids.

The lower portion of the Agglomeratic Slate formation of Kashmir is probably equivalent in age to the Fenestella Shales and, to be strictly consistent, would belong to this section of the chapter. The Agglomeratic Slate, however, forms part of the Panjal volcanics and is best described under the heading of that system which ranges from Middle Carboniferous through the Permian into the Upper Trias.

Karakoram.—The prominent peaks of the Skamri range, part of the Karakoram watershed, are composed of a thick sequence of white and grey crystalline limestones with belts of interbedded black shales; these shales in Punmah have yielded specimens of *Fenestella* and are evidently the equivalent of the Fenestella Shales of the Kashmir valley.[1]

Other parts of Kashmir.—Hayden suggests that a considerable part of the area mapped by Lydekker in Kashmir as "Panjal" may, from the descriptions, belong to the Po series of shale and quartzite. For instance, the slates, quartzites and sandstones recorded on the south side of the Lingti valley, a tributary of the Tsarap, appear to correspond so closely in character with the Po beds that they may be their northern continuation. In this connection it may be noted that *Conularia punjabica* and *Syringothyris cuspidata*, var. *lydekkeri* have been collected from a sandstone in the Ladakh valley.[2] As already noted, both Lower and Middle Carboniferous have been found in the Pir Panjal, between Budil and the Banihal Pass; the latter here consists of 2,000 feet of black shales and quartzites and conglomerates, containing well-preserved *Fenestella*, *Productus*, *Spirifer* and *Pecten* and overlying the Syringothyris Limestone. It is possible that in other parts of Kashmir the Lower as well as the Middle Carboniferous is present, for certain sections of his "Panjal system" described by Lydekker, in which slates and quartzites overlie limestones, recall the Spiti succession.[3] As we shall see, near Marbal and Kolahoi the Fenestella series has become involved in the local basal portion of the Agglomeratic Slate, and has been mapped and described under the latter term.

AFGHANISTAN AND PERSIA.

As already recorded, the Middle Carboniferous in Afghanistan is represented by the upper portion of the Helmand series. The Lower and Middle Carboniferous of Armenia, the Araxes valley and the vicinity of Lake Urumiya have not been found in central Persia, where the Middle division is represented by 1,600 feet of sandy beds in the Bakhtiari country, from one horizon of which *Sigillaria persica* Sow., has been collected; these beds lie upon the Upper Cambrian and are succeeded by 3,000 feet of fossiliferous limestones which are regarded as the equivalent of the Middle Productus Limestone of the Salt Range.[4]

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[1] A. Desio. *Geogr. Journ.*, LXXV, 403 (1930).

[2] C. Diener. *Pal. Ind.*, New Ser., Vol. V, Mem. 2, p. 54 (1915).

[3] H. H. Hayden. *Mem.* XXXVI, 58 (1904).

[4] J. A. Douglas. *Pal. Ind.*, New Ser., Vol. XXII, Mem. 6, 46 (1936).

UPPER CARBONIFEROUS AND PERMIAN.

"Marker" value of the Talchir horizon.—We come now to one of the best defined horizons in the Indian sequence, and one most useful for correlation purposes since it marks an important and widespread break between the great Dravidian group below and the Aryan group above. It is known as the Talchir stage and, according to the scheme of classification most generally accepted, corresponds to the Upper Carboniferous. The stratigraphical section now to be considered is that ranging from this horizon to the base of the Trias. The first area to be described will be that of the Salt Range, where the strata in question are well displayed and received early attention.

THE SALT RANGE, AND ITS TRANS-INDUS EXTENSION.

Classification—In the Salt Range of the Punjab, there is a stratigraphical gap between beds believed to be Cambrian in age and a sandstone series including a boulder bed which corresponds to the tillite characterising the Talchir or lowest subdivision of the great Gondwana system of the Peninsula. These boulder deposits, their widespread distribution, and their foreign representatives will be discussed more fully in the chapter on the Gondwana system. From the Talchir or Upper Carboniferous epoch to the end of the Permian, deposition was continuous in the Salt Range area, and there seems, in fact, to have been no extensive break between the Permian and Trias. The oldest member of this conformable succession was distinguished by Wynne as the Speckled Sandstone, a series usually, if not invariably, characterised at its base by the above-mentioned ancient boulder bed. When first differentiated, the speckled red sandstones were thought to be confined to the western parts of the Salt Range; at the same time a series of greenish sandstones, designated the "Olive group" and containing in what were regarded as its upper parts, fossils of reported Cretaceous age, was thought to be restricted to the eastern half of the range. It was Mr. H. Warth who proved, in the first place, that the speckled red sandstones are definitely present in the eastern parts of the Salt Range, though less prominent than they are further west; secondly, that the so-called "Olive group" consists of two portions of widely different age, the upper then supposed to be Cretaceous but now known to be Palæocene, the lower belonging to the same series as the speckled red sandstones which in the east they in a large measure replace; and thirdly, that this lower portion, consisting of greenish sandstones, predominates and is more in view in the eastern than it is in the western parts of the range.[1] Warth's generalised section need not be given, since the sequence has been reclassified by Mr. Gee. Near Makrach, the reddish purple and light-coloured sandstones, forming the lower part of Wynne's speckled sandstones, appeared to Gee to pass down gradually into the yellow-green sandstones of the lower portion of the old "Olive group" which here overlie the Boulder bed.[2]

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[1] *Rec.* XX, 117 (1887).

[2] *Gen. Rep. Rec.* LXII, 161 (1929).

For the whole sequence now under consideration in the Salt Range (Uralian and Permian) Gee has proposed the name, Shahpur, a system which he sub-divides as follows[1] :—

Shahpur system.	Productus Limestone series. (Permian).	(7) Upper Productus stage .		Maximum thickness 330 feet.
		(6) Middle Productus stage.	"Cliff Limestones."	Maximum thickness 480 feet.
			Glossopteris Beds.	Maximum thickness 80 feet.
		(5) Lower Productus stage .		Maximum thickness 170 feet.
	Nilawan series (Upper Carboniferous).	(4) Lavender Clay stage .		Maximum thickness 200 feet.
		(3) Speckled Sandstone stage .		Maximum thickness 460 feet.
		(2) Conularia Beds . .		Maximum thickness 80 feet.
		(1) Talchir Conglomerates .		Maximum thickness 360 feet.

The widespread and transgressive Talchir Conglomerate stage, often spoken of as the "Boulder Bed", extends not only throughout the whole length of the Salt Range with few interruptions, but is found also in patches in the trans-Indus continuation thereof. The upper limit of the Shahpur formation, though distinct, shows no evidence of the marked erosion which preceded the deposition of the basal stage. While the lower half of the system, the Nilawan series, is wholly composed of alternating arenaceous and argillaceous sediments, the upper half or Productus Limestone series is mainly calcareous.

Though fossil plants have been found at two horizons, Gee considers it improbable that widespread fresh-water conditions prevailed at any time during the deposition of the Shahpur beds. The sequence suggests deposition in shallow seas during the first half of the period, and deeper and clearer water suitable for the maintenance of a prolific marine fauna during the accumulation of the Productus limestones. The absence of the greater part of the Shahpurs in the eastern portion of the Salt Range is no doubt due to erosion at the end of the Mesozoic era, and there is good reason to conclude that deposition originally extended far beyond the present eastern limits of the beds.

A. NILAWAN SERIES.

The Nilawan series, named after the well-known ravine in which it is so well exposed—the Nila Wahan (Nilawan)—is prominent in the middle and western sections of the cis-Indus Salt Range and also in the Khasor range on the other side of the river. In the Nila Wahan gorge, 714 feet of these beds have been measured by Gee, but above Saiduwali in the Khasor range no less than 925 feet are present. It corresponds to the lower half of the Lower Marine series of eastern Australia, and to the Upper Carboniferous or Uralian of Europe.

Talchir Stage.—The Talchir stage consists of a fine-grained matrix of shale, sandy shale or sandstone, usually olive-green in colour and weathering into acicular fragments, through which are scattered blocks of hard rock, ranging in size to several cubic feet, almost invariably sub-angular and frequently showing faces that have been smoothed, polished and striated in the manner characteristic of glacier action; there may be only one such facet or there may be more than one. The unfacetted surfaces of the boulders are often seen to be pitted.[1] The fragments are composed for the most part of granite, felsite, slate, schist and quartzite - crystalline rocks which are absent in the Salt Range and whose nearest analogues are to be found 300 or 400 miles to the south in the granites and rhyolites of the Erinpura and Malani suites of Rajputana. At Warcha Mandi, for instance, the majority of the boulders consist of a biotite granite with quartz and orthoclase micrographically intergrown, which might be the Jalor granite of Rajputana, and have even closer resemblances to the granite of Waloria or that of Danta State;[2] others may have come from the Tusham area to the west of Delhi, and some are very close in composition to the Malani Rhyolite. A boulder from Chel hill is made of a rock similar to the Siwana (Malani) granite of Rajputana.[3] Among the rocks of the Kirana hills, which form a small inlier in the great alluvial tract forty or fifty miles south of the Salt Range scarp, are a devitrified rhyolite and some coarse-grained tuff-like types, which show distinct resemblances to the material of a few of the boulders in the Salt Range Boulder Bed, but the majority of the latter were found by Dr. Heron to be in no way similar to the Kirana rocks.[4] Mixed with the exotic fragments just enumerated, however, are numerous examples derived from the older Palæozoic beds of the Salt Range itself, more especially of the Magnesian Sandstone. On the west side of the Sardahi (Sardi) glen, for example, the Boulder Bed, some 40 feet thick, is made up of large fragments of the Magnesian Sandstone, a foot or more across, accompanied by a few boulders of crystalline rocks[5]; from Kusak a scratched boulder composed of the local Purple Sandstone has been collected.

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[1] Private communication. The section on the Salt Range is based largely upon material very kindly supplied by Mr. E. R. Gee and Dr. F. R. Cowper Reed, in anticipation of their respective memoirs on that area.

The evidence, taken as a whole, points to the south as the direction from which the bulk of the boulders were derived. Glacial though it undoubtedly is, the Boulder Bed differs from a typical tillite or boulder clay in the frequently sandy nature of its matrix and in its close association in places with fossiliferous marine deposits. The boulders of this area appear to have been, for the most part, erratics dropped by floating ice, and conditions of deposition were evidently estuarine or coastal.

Though often less than a foot thick, this stage is very rarely absent altogether. At the eastern end of the Salt Range, on the northwestern face of Jogi Tilla, some six to eight feet of the Boulder Bed with fragmentary plant remains are recorded by Wadia occurring in patches on a skin of "Salt Pseudomorph" shales covering a dip-slope of Magnesian Sandstone; it is succeeded here by 20-80 feet of Nummulitic beds.[6] Gee has failed to find it a short distance west of Jalalpur, and also in the adjoining Chambal Hill, but noted a thin deposit thereof overlying Salt Pseudomorph (Cambrian) beds in the Karangal ridge.[7] North of Baghanwala, the matrix of the conglomerates, which are from 20 to 60 feet thick, is alternately sandy and argillaceous; the lower part is often purplish red in colour, suggesting a derivation from the underlying Salt Pseudomorph rocks; fragments of the latter being sometimes recognisable among the pebbles. Westwards, the stage thickens and at Makrach is still resting upon the Salt Pseudomorph beds. Bewteen Khewra and Makrach, the stage, which in places is 75 feet in thickness, often includes more than one conglomerate horizon separated by greenish-brown sandstones and shales. West of Makrach, the Talchir stage oversteps the Salt Pseudomorph beds and is directly superposed on the Magnesian Sandstone, the next older stage of the Cambrian. Where it rests directly on the Magnesian Sandstone beds between Malot and the Nila Wahan, it is in places found to include numerous angular boulders of the latter series in its basal portions. Further west, the Magnesian Sandstone is overstepped in the same way till in the Nila Wahan (Nurpur Glen) the Boulder Bed rests upon the Obolus Shales, a still older stage of the Cambrian. North of Katha (Kattha ; Katta), the Boulder Bed, here very thin, rests upon the still older Purple Sandstone, from which the lower part of its matrix seems to have been derived.[1] On the plateau at Vasnal, the conglomerates are well exposed, directly overlying the Purple Sandstone. North of Wareha Mandi, they still rest on the Purple Sandstone, some of the boulders occurring in slight depressions of the upper surface of the sandstone. In the Amb glen and in the neighbourhood southwest of Sakesar except at Chittidil, the base of the Boulder Bed is sometimes in contact with the Purple Sandstone, and often with the Saline series[2] ; in the latter case the junction is described as disturbed, and the hard boulders show marked crushing and shearing in sections ranging over a distance of thirty miles along the range.[3] Near Chittidil, a short distance away from the Amb glen, the conglomerates, only a foot or two thick, overlie the Salt Pseudomorph stage. In the Amb glen, the conglomerates have increased in thickness to 12 or 14 feet and include a few angular pebbles of buff sandstone similar to that seen among the strata forming the upper part of the Purple Sandstone series ; the conglomerates are here succeeded by 12 or 15 feet of dark greenish grey pebbly shales, also belonging to the Talchir stage. To the northwest of Chhidru, the Boulder Bed lies directly on the Saline series, the junction again being a plane of marked thrusting. Northwest of Sakesar, where they overlie the Saline series, dark conglomeratic shales predominate and reach a thickness of well over 100 feet in some sections, whilst beyond Buri Khel, in the south and west sides of the Tradian hills, over 250 feet are recorded in several sections, and in the Sarin gorge north of Buri Khel as much as 363 feet.

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[1] F. R. Cowper Reed, G. de P. Cotter and H. M. Lahiri. *Rec.* LXII, 417 (1929).
[2] *Rec.* LXII, 418 (1929).
[3] F. R. Cowper Reed, G. de P. Cotter and H. M. Lahiri *Rec.* LXII, 418 (1929); T. H. D. La Touche. *Mem.* XXXV, 90 (1902); C. S. Middlemiss. *Rec.* XXV, 24 (1892)
[4] *Rec.* XLIII, 233 (1913).
[5] C. S. Middlemiss. *Rec.* XXIV, 22 (1891).
[6] *Rec.* LXIII, 128 (1930).
[7] *Rec.* LXVI, 115 (1932).

Perhaps the most interesting sections of the Talchir conglomerates are those in the southern slopes of the Sakesar ridge, where Mr. Gee found them resting in places on the top dolomite stage of the Saline series but transgressing laterally on to the red Salt Marl below. The tillites here are often of a dull purple colour near the base, and include pebbles of dolomite as well as of granite, quartzite and other rocks. According to Gee, the boulders show no signs of shearing and the junction has every appearance of being a sedimentary one. Where the Talchirs transgress on to the Salt Marl, fragments of red shaly marl, as well as pebbles of grey dolomite and very occasionally of gypsum, occur in the basal part of the superjacent formation.

On the other side of the Indus, at Saiduwali in the Khasor range, the Talchir conglomerate stage, lying upon what are looked upon as the representatives of the Salt Pseudomorph beds, is again very thick. The beds comprise from 250 to 270 feet of fragmentary, purplish, reddish-brown, grey and greenish shales, and bands of massive, greyish green, conglomeratic sandstone. Mr. Gee notes that the lower shales contain, in addition to the usual boulders of granite, quartzite and other metamorphic rocks, numerous pebbles of gypsum and dolomite obviously derived by erosion from the underlying beds which here consist of gypsum, dolomite and bituminous shale ; larger boulders of these particular rocks also occur. Some fifteen feet above the base of the stage, one large, sub-angular boulder of black, bituminous, vesicular, dolomitic shale, exactly like some of the shale in the subjacent gypseous group, measured three feet by two feet by two feet ; another slightly smaller boulder was observed in the immediate neighbourhood. The conglomeratic beds are overlain by brownish-green and red sandstones with clays, all typical of the sequence in the Salt Range, the correlation being confirmed by an examination of the heavy mineral residues by the geological staff of the Burmah Oil Company.

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[1] *Gen. Rep. Rec.* LXII, 161 (1929).
[2] C. S. Middlemiss. *Rec.* XXIV, 22 (1891).
[3] *Rec.* LXIX, 66 (1935).

Boulders occur at various horizons but are said to be more plentiful in the upper portions of this stage in the Khasor range ; here, some of the dark grey tough shales in the lower portions are reported to have yielded small fragments of grass-like plants or leaflets.[1] The boulders of these parts are described as well rounded, and composed chiefly of metamorphic and crystalline rocks, among which a granite with a red felspar is common ; at Kafir Kot they also include dark basalt, limestone, quartzose and other indurated rocks. The blocks are occasionally of considerable size ; some of them are highly polished and some show striations ; by weathering, they give rise to earth pillars. Four small patches of the Talchir boulder bed have been mapped along the foot of the Khasor range.

Conularia Beds.—The Conularia Beds, grading down into the Talchir conglomeratic sandstones and shales, indicate the incoming of more regular conditions of deposition. Beween 50 and 75 feet in thickness, they form an easily recognisable group, passing up into the red or purple beds of the Speckled Sandstone stage. In the eastern part of the Salt Range, they contain the remarkable *Eurydesma-Conularia* fauna, while in the middle portion of the range they have yielded Lower Gondwana plants and some interesting bivalves. Predominantly olive-green in colour, as Mr. Gee remarks, they resemble their homotaxial equivalent sandstones and shales overlying the Talchir conglomerates of the Peninsula.

The Conularia Beds make their appearance between the Boulder Beds and the Palæocene in the upper scrap-slopes of the Salt Range, west of Ara, and are well seen southwestwards as far as Khewra, the superjacent Speckled Sandstone appearing and thickening in a westerly direction. The stage includes olive-green, brown-weathering sandstones, some of which are gritty or contain thin pebbly bands, and shales, with occasional bands of sandy carbonaceous shale. In the eastern half of the range, it has yeided a fauna of extreme interest. This fossiliferous layer consists of a very thin bed of brownish sandy nodules, oval in shape and all of much the same size. Many of the nodules, but not all, are crowded with specimens of the following forms which, numerous though they are, do not belong to more than about twenty-one species[2]:

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[1] A. B. Wynne. *Mem.*, XVII, 29 (1880).

[2] Identified partly by Waagen and partly by Cowper Reed (*Pal. Ind.*, New Ser, Vol. XXIII, Mem. 1. p. 28 (1936).

Chætopoda,—
- *Serpulites undulatus* Waag.,
- ,, *warthi* Waag.,
- ,, *tuba* Waag.,

Brachiopoda—
- *Discina* sp.,
- *Discinisca warthi* Waag. (close to *Discina kashmiriensis* Dav. from the Carboniferous of the Kashmir valley).
- * *Spirifer vespertilio* Sow.,
- * *Martiniopsis darwini* Morr.,
- * *Chonetes cracowensis* Ether.,

Lamellibranchiata—
- * *Sanguinolites* cf. *mitchelli* de Kon.,
- ,, *tenisoni* de Kon.,
- *Nucula* sp.,
- *Pseudomonotis subradialis* Waag.,
- *Aviculopecten* cf. *serdobowæ* Fred. (a Russian form ; Waagen's "*A.* cf. *limæformis* Morr." Compare also *A. cunctatus* from the Agglomeratic Slate of Kashmir),

Gastropoda—
- * *Pleurotomaria nuda* Dana,
- *Bucania warthi* Waag.,

Pteropoda—
- * *Conularia lævigata* Morr.,
- ,, *punjabica* Reed (a form found in the Fenestella series of Kashmir),[1]
- * ,, *warthi* Waag. (found in the "Permo-Carboniferous" of Western Australia ; close to *C. quadrisulcata* Mill. from the Lower and Middle Carboniferous of Europe),
- ,, *salaria* Reed, (closely allied to *C. derwentensis* Johnst. from the "Permo-Carboniferous" of Tasmania),
- ,, *chelensis* Reed.

*=Australian species, all except one from the Lower Marine series, below the Coal Measures of New South Wales.

A peculiarity of these 21 species is that nearly all of them are of small dimensions. By far the commonest types are the *Conularia*, the next in numbers being the specimens of *Serpulites*. The frequent occurrence of *Discina*, *Discinisca* and *Serpulites* points to a muddy beach. The nodules were at first regarded by some as transported, water-worn pebbles, by others as concretions, but there is much in Mr. R. D. Oldham's final suggestion that both types are present. In favour of a concretionary origin are the facts : (i) that the fauna is very uniform and represents a single geological horizon, (ii) that the nodules are not irregularly distributed but are restricted to a very thin layer which is very regular in its horizontal distribution, (iii) that most of the specimens show no unquestionable signs of rolling, and (iv) that in the Chel Hill, *Conularia* and other fossils have evidently formed, a nucleus for the deposition of carbonate of lime which has hardened the enclosing sandstone for a few inches. On the other hand, the nodule band is sometimes a thin layer of gravel, which is not the kind of rock in which to expect concretionary growth, and, furthermore, some of the nodules show abrasion of the surface and truncation of the fossils.[2] There is little doubt that the bulk of the nodules are of concretionary origin, and that some of them at least have been rolled and transported for short distances; elsewhere, the thick, greenish, deeply weathered sandstones enclose considerable numbers of casts of indeterminable bivalves.[1] In some cases casts of both valves of molluscan shells have been found together in the nodules.

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[1] It is doubtful whether Waagen's identification of the Australian species, *Conularia tenuistriata* McCoy is correct ; possibly a variety of this species is present.

[2] W. Waagen. *Rec.* XIX, 25 (1886) ; R. D. Oldham. *Ibid.*, 127 (1886); W. Waagen. *Rec.* XXI, 118 (1888).

Some fossils, fortunately discovered in a green sandstone band, occurring sometimes below and, apparently, sometimes above the nodule bed, prove definitely that the fauna of the nodules is a very close indication of the age of the strata in which they occur, for these fossils are regarded by Dr. Cowper Reed as approximately contemporaneous with those of the nodules, though of a somewhat different faunistic facies indicating slightly different marine conditions. They consist of the following[2] :—

Bryozoa—

Fenestella (*Fenestrellina*) *fossula* Lonsd. (A. K.) (found in the Upper Marine series of Tasmania).

Brachiopoda—

Dielasma dadanense Reed (close to *Terebratula amygdala* Dana from the "Permo-Carboniferous" of New South Wales and to Diener's *D.* cf. *lidarense* from Kashmir) (A.K.).

Lamellibranchiata—

Aviculopecten cf. *cunctatus* Reed (species found in Kashmir).
Palæolima sp.
Pterinea cf. *lata* de Kon., (A.).
Nucula pidhensis Reed (closely allied to *Tellinomia darwini* de Kon. from the "Permo-Carboniferous" of Tasmania and N. S. Wales) (A.).
Parallelodon sp.
Mæonia (*Cleobis*) cf. *gracilis* Dana. (a variety of the type is found in the Agglomeratic Slate of Kashmir; the type itself occurs in Australia) (A.K.).
Astartila cf. *ovalis* (McCoy) (A.K.).
,, (?) *salaria* Reed (close to Australian forms), (A.).
Astartella (?) *pindensis* Reed,
,, (?) *simulans* Reed, (comparable with *Pachydomus danai* de Kon from Australia), (A.).
Cardiomorpha pinguis Reed (K.)
,, (?) *pusilla* (McCoy) (A.).
Liebea sp.,
Myalina ? sp.,
Eurydesma cordatum Morr. (A.).[3]
,, ,, var. *mytiloides* Reed (probably the equivalent of Waagen's *E. globosum*). (A.K.).
,, *hobartense* (Johnst.). var. *bigener* Reed (abundant; type found in Australia) (A.)
,, ,, ,, var. *rotundata* Reed. (A.).
,, *demissum* Reed (resembles *E. ellipticum* Dana from Australia) (A.).
,, *punjabicum* Reed (cf. *E. cordatum* var. *subquadrata* Reed, and *E. cordatum*, var. *compressa* Reed from Kashmir) (K.).
,, *punjabicum* var. *elongata* Reed,
,, *subovatum* Reed (probably equivalent to some of Waagen's *E. ellipticum*).
,, *æquale* Reed,
,, *obscurum* Reed (much resembles *Pachydomus gigas* McCoy from New South Wales) (A.).

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[1] A. B. Wynne. *Mem.* XIV, 104 (1878).

[2] F. R. Cowper Reed. *Pal. Ind.*, New Ser., Vol. XXIII, Mem. I, p. 4 (1936).

[3] The identification by Waggen of the two Australian species, *E. globosum* Dana and *E. ellipticum* Dana, among the fossils from the *Eurydesma* bed of Sandowal is questioned by Cowper Reed.

Eurydesma subobliquum Reed, (cf. *E. globosum* from Kashmir ; type found in Australia) (A.K.).
,, *pertenue* Reed,
,, *amygdalinum* Reed,
,, *perversum* Reed.

A. forms identical, allied or comparable with species from Australia.
K. forms identical, allied or comparable with species from Kashmir.

Considering the collections from the nodules and from the adjacent sandstone as one fauna, the most noticeable point about it is the very large proportion of species which are identical or comparable with forms found in the upper part of the Lower Marine series of New South Wales, a stage which there is good reason for placing at the top of the Upper Carboniferous. The presence in both cases of large boulders of foreign rock exhibiting distinct glacial smoothing and striation, embedded in fine-grained silt, makes the correlation definite and incontrovertible. In Australia, *Eurydesma*, that curious lamellibranch genus which has so far not been found outside Australia, South Africa, Argentina and India, characterises two distinct stratigraphical horizons, one containing *E. hobartense* and occurring below the *Gangamopteris* horizon, and the other containing *E. cordatum* and occupying a higher position in the Lower Marine series.[1] Cowper Reed suggests that, while the Salt Range *Eurydesma* and *Conularia* zone is the equivalent of the *E. hobartense* horizon of Australia, the Kashmir occurrences correspond to the higher *E. cordatum* horizon. In South Africa, where we also find strikingly close resemblances, *Eurydesma* (*Eurydesma globosum*) is typical of the Upper Dwyka Shales ; in South-West Africa, the dark shaly " Eurydesma Beds ", as they have been called, as well as the associated Boulder mudstones, contain calcareous phosphatic concretions which have yielded species of *Conularia, Aphanaia* and *Orthoceras* and the remains of fishes.[2]

In the hills north of Khewra, Gee has found large blocks of silicified fossil wood of indeterminable relationship in the greenish grey sandstones of this stage.

Near Katwahi (Kathwai), in the middle of the range, the Conularia stage was found by Gee to include some dark grey and black carbonaceous shales containing well-preserved leaf impressions and spores of *Glossopteris, Gangamopteris* and other Lower Gondwana plants, along with a few small lamellibranchs believed to be related to certain South African forms. The spores, which are winged, have been examined by Miss Chinna Virkki who has recognised two species, similar to spores found in the Australian equivalents of the Lower Gondwanas and closely associated with *Glossopteris* leaves ; the spores from Katwahi resemble *Pityosporites sewardi.*[3]

The lamellibranchs, as determined by Dr. Cowper Reed[4] are :—

Palæomutela cf. *oblonga* (Jones) (species found in Tanganyika and Nyasaland),
,, cf. *neglecta* (Jones) (species found in Tanganyika ; very close to the Russian species, *P. keyserlingi* Amal.),
,, cf. *subparallela* Amal. (a Karoo species),
,, cf. *rectodonta* Amal. (species found in Tanganyika),
,, (?) *singularis* Reed.

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[1] The higher is assigned by David and Süssmilch to the Lower Permian, though some authorities prefer to retain both horizons in the Upper Carboniferous. The specific differences between *Eurydesma cordatum* and *E. hobartense* have recently been questioned.

[2] A. L. Du Toit. " Geology of South Africa ", 2nd. Edin., pp. 248, 298 (1939).

[3] *Proc. Ind. Acad. Sci.*, VI, No. 6, Sect. B, 428-431 (1937). From these beds also come presumably *Samaropsis* sp., *Cordaicarpus* sp. and a new species of *Ottokaria* (*Journ Ind. Bot. Soc.*, XVIII, 202 (1940).

[4] *Rec.* 74, 474 (1939).

Palæanodonta salaria Amal. (closely resembling *P.* cf. *fischeri* Amal. from the Martaban district of Burma, and *Anthracomya bellula* Bolton from the Lancashire Coal Measures),

Carbonicola (?) *indica* Reed (close to *C. angulata* de Ryckhot and *C. similis* Brown, both from the Donetz basin),

Carbonicola (?) *semielliptica* Reed,

„ (?) *recondita* Reed (closely resembling *C. oslancis* Wright and *C. similis* from the British Coal Measures),

Carbonicola (?) *kathwaiensis* Reed,

Anthracomya shahpurensis Reed (almost identical with *A. pruvosti* Tschern. from the "Barren Red Measures" of Clydesdale, Scotland),

Anthracomya subquadrata Reed,

Anthraconauta punjabica Reed (resembling *A. scotica* (Eth. junr.) from the British Carboniferous),

Anthraconauta tenuistriata Reed,

Cytherella sp.

Owing to divergence of opinion regarding the specific reference of many specimens belonging to the genera *Palæomutela*, *Carbonicola* and *Palæanodonta* in Europe, Africa and China, and also because of our ignorance of the internal characters and dentition of the Salt Range forms, they cannot be accepted as showing any precise stratigraphical horizon; their presence, however, does not conflict with the deduction of an Upper Carboniferous age.

It is interesting to record the presence, in the basal Boulder bed of the Nila Wahan, in the western half of the Salt Range, of a very small proportion of pebbles of a soft bluish rock, some of which have yielded specimens of *Conularia*, *Serpulites* and other fossils.[1]

Speckled Sandstone.—Commencing in the east, to the northeast of Khewra, the Speckled Sandstone stage is seen underlying unconformably the basal Tertiary (Palæocene). At first only the lowest beds are present, but higher horizons make their appearance as the beds are traced westwards to Makrach and Malot, the stage steadily increasing in thickness and becoming overlain by Gee's "Lavender Clay stage". The Speckled Sandstone beds are well developed throughout the middle and western sections of the Salt Range and are again prominent in parts of the Khasor range on the other side of the Indus. From about 80 feet north of Khewra, they increase to over 150 feet in the Makrach area, to over 200 feet in the Sardahi (Sardi) gorge, and reach a maximum of 464 feet in the western slopes of the Nila Wahan. Further west, the thickness varies between 200 and 300 feet, but the soft clays of the formation appear in several places to have been squeezed out by faulting, and the reduction in thickness seems attributable, partly at least, to faulting and shearing. At Saiduwali in the trans-Indus area, Gee has measured 426 feet.

The Nila Wahan section which is typical of the stage, is described by Gee as follows :—

(Lavender Clay stage . . . . 190 feet.)	
Massive, comparatively soft, speckled sandstones, alternating with dark red and chocolate-coloured clays, with some dark purple clay bands near the top	195 feet.
Massive, soft, pinkish, dirty grey and reddish sandstones, often gritty and including small pebbles chiefly of white and pink quartzite, with thin bands of red and buff shaly sandstones and shales . .	125 „
Dark red and chocolate-coloured clays, with a 9-foot band of massive, pinkish sandstone in the middle	130 „
Dark chocolate-red sandstones, some gritty, others argillaceous and flaggy, with dark red and greenish shales	14 „
	464 „
(Olive-green sandstones of the Conularia Beds . . . . . 60 feet.)	

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[1] H. Warth. *Rec.*, XX, 117-119 (1887).

Ripple-marking and current-bedding are sometimes prominent, and certain of the coarser sandstones are felspathic and have an arkosic appearance. A characteristic feature, in which they resemble some of the Barakar and Mahadeva sandstones of the Central India Gondwana, is the projection from the weathered surface of numerous small wart-like concretionary knobs, an effect due to a local concentration of the calcareous cement. Some of these coarse sandstones include small, sub-angular pebbles of red and white felspar, along with more rounded pebbles of quartzite and other metamorphic types and of igneous rocks. Most of the sandstones belonging to this stage are definitely softer than the Purple Sandstone lower down in the Salt range succession, but some of the harder, dark red types among the Speckled Sandstone beds can be matched in the older formation. Middlemiss, speaking of the Sardahi glen section, notes that the sandstones of the series are fine-grained in the lower parts, the grains of sand being always angular or sub-angular. The higher horizons are very coarse-grained and conglomeratic, with angular or sub-angular pebbles.[1] The smaller pebbles are composed chiefly of vein quartz and a compact red felsite, the large ones chiefly of the red felsite; the pebble material also includes the Magnesian Sandstone and a dark quartzite, but none of the coarsely crystalline red granites so common in the basal boulder bed. The conglomeratic character of the series increases towards the west. At Pidh (Pid), the red sandstones contain petrified wood, and brown nodules, some three inches thick, with crystals of calcite, barytes and other minerals inside.[2]

Lavender Clay.—The Lavender Clay stage comes in near Malot and thickens rapidly westwards in the Sardahi gorge and the Nila Wahan, attaining a thickness of 190 feet in the latter. Westwards, it persists throughout the range, never exceeding to any extent this figure, and often becoming much thinner as a result of shearing or of collapse of the overlying Productus Limestone. At Saiduwali, across the Indus, about 150 feet of strata are assigned to this stage.

The stage is described by Gee as consisting largely of dark purple, bluish-green and lavender clays with very subordinate sandy shales and sandstones. The lavender and purple clays include in places small nodules of copper pyrites which weather out on the surface after periods of heavy rain. Thin flakes of gypsum occur and yield rapidly to the weather. In the upper part of the stage there are found occasional bands of white argillaceous sandstone containing a few fish scales; also high up in the sequence a band of purplish red chert, ranging up to about 2½ feet in thickness, is seen in places. Stringers of carbonaceous shaly material, sometimes with indistinct plant remains, are not uncommon. The passage up into the Lower Productus beds is quite conformable.

B. PRODUCTUS LIMESTONE SERIES.

Distribution and classification.—The Lavender Clay stage of the western half of the Salt Range passes up into a thick series of beds which are absent in the eastern half, and have long been known for the wealth of the fossil remains they contain. These beds of the Productus Limestone series form widespread outcrops, particularly in the lower complicated plateau areas to the north of Kund, Jabbi (Jabi) and Warcha. In the east, they appear to have been completely denuded away towards the end of Mesozoic times. They make their first appearance in the fine cliffs on the west side of the Nila Wahan, where the Lower Productus beds come in conformably above the Lavender Clay stage and increase in thickness westwards. The Lower sub-division alone is seen near Pail where it has been thrust over Tertiary beds (Kamlials). Farther south, in the Kalra Wahan, north of Katha, the Middle division comes in and attains a thickness of 250-300 feet, while further to the southwest the Upper sub-division appears north of Jabbi in the form of softer, fossiliferous, green sandstones and impure limestones, some 150-200 feet thick[1]. The most extensive sections of the series occur in the Son plateau where all three sub-divisions are present. In the upper part of the Nursinghpur gorge, the Productus Limestone has been overfolded. Along the south side of the Sakesar ridge and in certain sections of the more westerly portions of the range, it is disturbed by complex fold faults and overthrusts, but to the north of Warcha Mandi, in and above the Jarhanwala ravine, a complete section of the formation, some 700 feet thick, has been examined and described in detail by Cowper Reed, Cotter and Lahiri[2] ; further west the series thickens to about 850 feet in the vicinity of Chhidru. A fine section of the Middle and Upper stages is exposed in the Nammal (Namal) gorge (the " Bakh ravine " of Wynne) near Musa Khel, and of the Lower stage in the foothills a short distance to the south. The thickness exposed in the Nammal gorge is about 710 feet ; by adding to this a further 180 feet for the Lower stage which is not exposed in this section, Gee arrives at a total maximum figure of about 900 feet for the whole Productus Limestone series, a figure far in excess of Wynne's estimate.

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[1] C. S. Middlemiss. *Rec.*, XXIV, 22 (1891).

[2] H. Warth. *Rec.*, XX, 118 (1887).

Further northwest, the series is well represented in the Tredian hills but disappears at Khairabad. On the other side of the Indus, the upper half of the series is seen near Kalabagh and, according to Wynne, as four small isolated patches in the Maidan range along the foot of the scarp. A wide continuous outcrop covers the greater part of the Khasor range, where it is well developed and similar lithologically to its exposure in the western part of the cis-Indus Salt Range ; Gee estimates the thickness of the series at Kingriali to be at least 750 feet. An anticlinal inlier is seen to the south of Paniala, and a small patch at the base of the Sheikh Budin scarp in the Marwat (" Mohrut ") range behind the Khasor.

The limestones of this formation form noticeable scarp features which, however, are less regular than the scarp of the Nummulitic Limestone above. Many of them are magnesian, but as we ascend in the succession, they tend to become purer, an effect, presumably, of the more complete transgression of the sea in which they were deposited ; the upper horizons include arenaceous and marly strata, and are said to pass up without any visible break into the Ceratite beds of Triassic age. No sign of unconformability can be detected among the Productus Limestone beds, though Gee utters the warning that certain junctions within the sequence may possibly represent time intervals ; some of these appear to be less transitional than the passage up from the Lavender Clay into the Lower Productus beds.

Waagen introduced a number of stage names for a further sub-division of the Productus Limestone formation, but these are impossible to follow in the field, even if they have sufficient significance and palaeontological individuality to justify their creation ; they are mentioned in brackets below for ready reference since they have been widely used in various publications. Gee's classification is placed beside them :—

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[1] *Rec.*, LXVI, 115 (1932) ; *Gen. Rep. Rec.*, LXVII, 53 (1933).

[2] *Rec.*, LXII, 421 (1929).

*(Chidru beds)	Upper Productus stage	Maximum thickness 330 feet.
(Jabi or Cephalopod beds)		
(Khundghat beds)		
(Kalabagh beds)	Middle Productus stage	Cliff Limestones ; maximum thickness 480 feet. Glossopteris beds ; maximum thickness about 80 feet.
(Virgal beds)		
(Katha beds)	Lower Productus stage	Maximum thickness 170 feet.
(Amb beds)		

The bed immediately below the *Glossopteris*-bearing carbonaceous shales is a hard, regular, easily recognisable, brownish dolomitic limestone, standing out from the hill-slopes. The carbonaceous shales are often hidden beneath the scree of the overlying limestones and somtimes show a lithological transition into the latter. The top of the Cliff Limestones is marked by a thin, marly, highly-fossiliferous bed crowded with specimens of large *Productus*. This is capped by the softer, gentler-sloping Upper Productus beds, the base of which is often a dull green sandy shale, up to 12 feet in thickness and sometimes carbonaceous. The top of the Upper stage is a comparatively hard, usually brownish, calcareous sandstone, or limestone, to the upper face of which the flaggy, grey Ceratite limestones of the Trias firmly adhere.

Lower Productus Limestone.—In the Lower Productus stage, pure limestones are subordinate, the prevailing beds being arenaceous limestones and calcareous sandstones, with some shales and sandy shales which are often carbonaceous. The basal beds are full of fossils and in this feature contrast strongly with the lithologically not very dissimilar beds of the Speckled Sandstone, in the upper part of which no fossils have been found. The calcareous element in the Lower Productus stage increases generally from below upwards.

As a much crushed outcrop, the Lower stage occurs between the Nilawan series and the Nummulitic rocks of the southwestern side of the Vasnal inlier on the plateau northwest of Nurpur. It reaches its full development of 130-170 feet at Katha and retains its thickness westwards. It is exposed in a number of sections in the Tredian hills and is readily recognisable in the Khasor range across the Indus where it overlies the Lavender Clay stage of the Nilawan series ; its thickness above Bilot is estimated by Gee at 150 feet. The fauna of the Lower Productus Limestone is given in the following pages.

Middle Productus Limestone.—The Middle division of the Productus Limestone series is the most conspicuous, owing to the rugged and precipitous cliffs and dissected plateaux to which its higher member gives rise in the western portion of the range. The beds make their appearance northeast of Katha, thicken rapidly westwards and are well exposed in the principal gorges. Their fauna is listed in the following pages.

The Lower Gondwana Plant beds, first found by Reed, Cotter and Lahiri in the Jarhanwala section and afterwards by Gee near the exit of the Dhodha Wahan below Sakesar as well as in the Golewali gorge, include carbonaceous shales, sandstones and impure limestones, and are often obscured by scree. At their thickest they are from 45 to 50 feet thick.

The Cliff Limestones swell to 120 and 150 feet in the main Katha gorge and, by additions to their top, to 240 feet in the Lunwala gorge north of Nali ; in the Golewali gorge and the neighbourhood of Chhidru they have increased to about

360 feet and reach a maximum of 480 feet in the Nammal gorge. Further north-west, the Cliff Limestones form precipitous outcrops in several gorges in the Tredian hills and display an estimated thickness of about 400 feet. These beds are mainly light grey in colour, but are sometimes white, cream or purplish in tint. For the most part they consist of very pure, fine-textured, crystalline limestone, but subordinate marly and dolomitic varieties and occasional flaggy sandy bands also occur. Certain horizons are full of fossils, which are usually difficult of extraction, the very numerous specimens obtained having been derived mostly from the interbedded marly layers. Some of the white and cream bands are crammed with crinoid stems. Corals are common and in places are seen to have accumulated in great reefs which show no traceable bedding. Silica is present in varying quantity and sometimes forms large flinty concretions ; it is more prevalent in the higher portions of the stage where the fossils are often beautifully silicified, especially at Musa Khel. The top of the Cliff Limestones has been found, by Gee, often to include a thin marly, highly fossiliferous bed crowded with large *Productus*. In the trans-Indus area the Cliff Limestones are widespread and well developed in the Khasor range, reaching thicknesses of 300 to 400 feet.

Upper Productus Limestone.—The Upper Productus stage appears first in the scarp slopes northeast of Kund, and increases rapidly in thickness to over 170 feet southwest of Katwahi, to 290 feet in one of the branches of the Golewali stream and to a maximum of about 330 feet in the Chhidru area.[1] In the Nammal gorge and the Tredian hills, thicknesses of the order of 225 feet are seen, and the stage is well developed in parts of the Khasor range on the other side of the Indus. The Upper stage is made up of comparatively soft beds, usually forming gentle slopes, and often capping the dip slopes of the Cliff Limestones. The basal bed is frequently a dull green, sandy and sometimes carbonaceous shale, up to 12 feet thick. The rest of the sequence is made up of calcareous sandstones, marls and harder limestones, with bands of greenish or brownish sandy shale ; rust-coloured, ferruginous dolomites are also present. Like the Middle, the Upper stage is impregnated with silica, and the abundant fossils are always silicified, though in most cases only on the inner and outer surfaces of the shell.

Fauna of the series.—The Productus Limestone has long been known for the wealth of organic remains found therein, and for the association, especially in the Upper division, of ammonoids of Palæozoic type with brachiopods. The profuse fauna of this formation has been the subject of several publications[2], the latest of which is from the pen of Dr. Cowper Reed.

The following lists[3] refer to collections made by Mr. E. R. Gee and determined by Dr. Cowper Reed, supplemented by forms determined by Dr. Waagen and recognised but not redescribed by Dr. Cowper Reed (marked " R ") and by recent collections from the Warcha area formerly described and recently corrected by Dr. Cowper Reed (marked*) ; unrevised determinations by Waagen are so indicated.

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[1] F. Noetling. *Neues Jahrb. f. Min. Geol. u. Pal.* Bd., XIV, 369-471 (1901).

[2] W. Waagen. *Pal. Ind.*, Ser XIII, Vol. I (1879) and Vol. IV (1889-1891) ; F. R. Cowper Reed. *Ibid.*, New Ser., XVII (1931) ; *Rec.*, LXII, 422 (1930) ; *Pal. Ind.*, New. Ser., XXIII, Mem. 2 (1944) and E. R. Gee's memoir (manuscript) on the Salt Range.

[3] Compiled with the assistance of lists very kindly supplied by Dr. Cowper Reed, pending the publication of his memoir. Judging from the discrepancies in the precise provenance of several of the species between Dr. Cowper Reed's lists (based on Mr. Gee's collection) and those of Dr. Waagen, the Geological horizon recorded by the latter authority—lower, middle or upper sub-division—is not always correct, even after allowance is made for the different limits of these sub-divisions adopted by Dr. Waggen and by Mr. Gee. See *Pal. Ind.*, New Ser. Vol. XXIII, Mem. 2 (1944); *Ibid.*, Vol. XVII, (1931), *Ibid* Ser. XIII, Vol. I (1879–1887) and Vol. IV (1889 and 1901).

Lower Productus Limestone.

Foraminifera—

* *Fusulina* (*Parafusulina*) *kattaensis* Schw.,
* ,, (*Schellwienella*) *longissima* Moll.

Crinoidea—

* *Cyathocrinus* sp.,

Bryozoa—

* *Polypora sykesi* de Kon.,
* *Geinitzella* sp.,
* *Domopora* (?) *ambigua* Reed,
* *Stenopora ovata* Lonsd.,

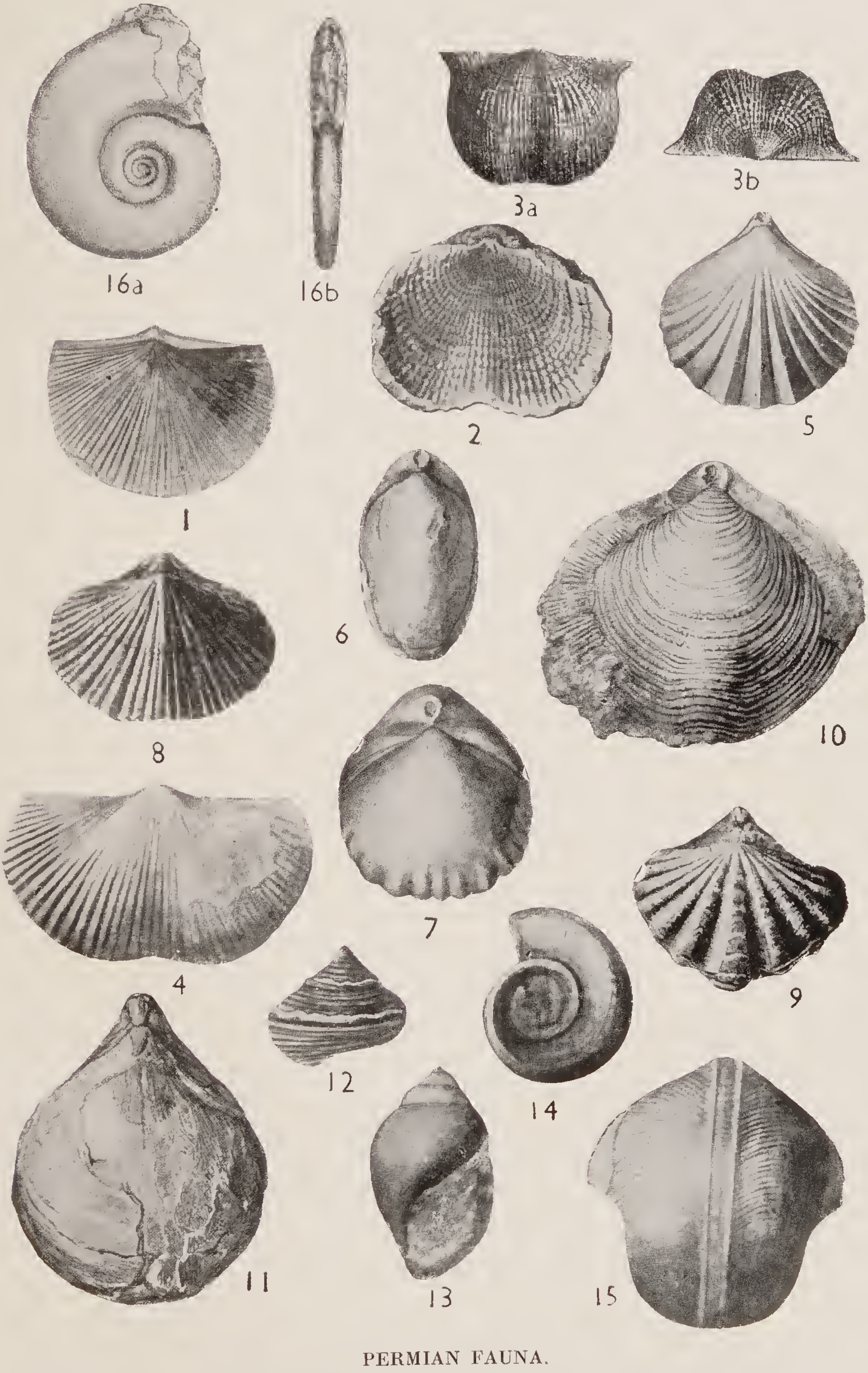
Vermes—

* *Spirorbis helix* King,

Brachiopoda—

Orthis (*Schizophoria*) *indica* Waag.,
R. ,, (*Rhipidomella*) *incisiva* Waag.,
* ,, ,, cf. *pecosi* Marcou (species found in China),
Orthotichia morgani Derby (found in Bolivia),
,, *bistriata* Reed,
Streptorhynchus mistus Reed,
R. ,, *capuloides* Waag.,
R. ,, *lenticularis* Waag.,
,, (*Schuchertella*) *praeceps* Reed,
Derbyia buriensis Reed,
,, ,, ,, var. *diversa*, Reed.
,, cf. *buchi* d'Orb. (species found in S. America, Texas, Russia and Persia),
R. *Productus* (*Dictyoclostus*) *spiralis* Waag.,
,, (,,) ,, var. *redacta* Reed,
,, (,,) cf. *leplayi* de Vern. (species found in Russia),
,, (*Buxtonia* ?) cf. *yabei* Frech (species found in China),
,, (*Taeniotherus*) *notabilis* Reed,
,, (,,) *cotteri*, Reed.
,, (*Overtonia* ?) *rudis* Reed,
Marginifera quadrata Reed,
,, *vestita* Reed,
,, *protracta* Reed,
,, *praenuntia* Reed,
,, *khairliensis* Reed,
R. ,, *transversa* Waag.,
,, ,, ,, var. *baralensis* Reed,
R. ,, *echinata* Waag.,
,, ,, var. *cognata* Reed,

R. ,, *ovalis* Waag.,
R. ,, *excavata* Waag.,
,, cf. *helica* (Abich), (species found in Armania)
,, cf. *morrisi* Chao (species found in China)



PERMIAN FAUNA.

1. *Streptorhynchus* (*Schuchertella*) *purdoni* Reed. 2. *Productus* (*Dictyoclostus*) *genuinus* Kutorga. 3 (a,b). *Marginifera himalayensis* Dien. 3a: dorsal view. 3b: apical view. 4. *Chonetes* (*Plicochonetes*) *simulata* Reed. 5. *Rhynchopora ? complanata* Reed. 6. *Dielasma truncatum* Waag. 7 *Notothyris inaequiplicata* Reed 8. *Spirifer* (*Purdonella*) *conformis* Reed. 9. *Spiriferina* (*Spiriferellina*) *cristata* Schlotheim var. *commixta* Reed. 10. *Athyris* (*Cleiothyridina*) *interposita* Reed. 11. *Spirigerella minuta* Waag. 12. *Pleurotomaria* (*Phymatopleura*) *uchhaliensis* Reed. 13. *Macrocheilina* (*Sphaerodoma*) cf. *intercalaris* Meek and Worthen. 14. *Euomphalus* (*Schizostoma*) *oldhami* Reed. 15, *Bellerophon equivocalis* Reed. 16 (a,b). *Xenaspis carbonaria* Waag.

G. S. I., Calcutta.

Brachiopoda—*contd.*
Strophalosia densispinosa Reed,
R. ,, (? *Heteralosia*) *nodosa* Waag.,
,, ,, ,, ,, var. *plaelonga* Reed,
R. ,, ,, *p. Licosa* Waag.,
,, (*Heteralosia*) *tenuispina* Waag.,
,, (,,) *sublamellata* Reed,
,, (*Bilotina*) *subtecta* Reed,
,, (*Strophalosiina*) *costata* Waag., var. *subrotunda* Reed,
Aulosteges wangenheimi de Vern., var. *rostrata* Reed,
,, *medlicottianus* Waag.,
,, *trimuensis* Reed,
,, *wynnei* Reed,
,, *virilis* Reed,
Chonetes carbonifera Keys, var. *vialis* Reed,
,, (*Paeckelmannia*) *ambiensis* Wagg.,
Chonetella (?) *indica* (Waag.)
Pugnax (*Pugnoides* ?) *tantillus* Reed,
Rhynchopora cf. *variabilis* Stuckenb. (species found in Russia and Nova Zemba),
Terebratuloidea ornata Waag., var. *uniplicata* Reed,
Dielasma trimuense Reed,
,, *nexile* Reed,
,, *plica* (Kut.) var. *arcuata* Reed,
,, *truncatum* Waag., var. *misrikhanensis* Reed,
,, *hochstetteri* (Toula) (Found in Bolivia and Persia).
,, ,, , var. *personata* Reed,
,, ,, , var. *semicarinata* Reed,
,, *vicinale* Reed,
,, *juresanense* Tschern. (found in Russia).
,, *ambiense* Reed,
,, *sultanense* Reed,
,, *subelongatum* Grab., var. *kundensis* Reed,
,, cf. *moelleri* Tschern. (species found in Russia and China),
,, cf. *darvasicum* Tschern. (species found in central Asia),
,, (?) *ovoidale* Reed,
Notothyris praelecta Reed, var. *naruensis* Reed,
,, *lochardi* Mansuy, var. *oviformis* Reed (*forma typica* found in Indo-China),
Dielasmina perovalis Reed,
Hemiptychina (?) *inflata* Waag.,
,, (?) *amygdala* Reed,
,, (*Beecheria*) *sublaevis* Waag. (perhaps a variety of *H. himalayen*),
Hustedia indica (Waag.), var. *baralensis* Reed,
,, *sulcata* Reed,
Uncinella paucicostata Reed,
,, *middlemissi* Dien. (found also in the Fenestella beds of Kashmir),
R. *Spirifer* (*Neospirifer*) *marcoui* Waag.,
,, (,,) ,, ,var. *undata* Reed,
,, (,,) *trimuensis* Reed,
,, (,,) ,, , var. *transvecta* Reed,
,, (,,) cf. *orientalis* Chao (probably equivalent to Waagen's "*S. striatus*"; S. *orientalis* occurs in China),

Brachiopoda—*contd.*
Spirifer (*Neospirifer*) *cameratus* Mort., var. *curta* Reed (*forma typica* an American species),
,, (,,) cf. *kimsari* (Bion) (species found in the Agglomeratic Slate of Kashmir),
,, (,,) cf. *subfasciger* Lich. (species found in Russia),
,, (*Spiriferella*) cf. *saranae* de Vern. (species found in Russia),
,, (*Paeckelmannella*) *varuniformis* Reed,
,, (,,) *middlemissi* Dien., var. *biplicata* Reed (*forma typica* found in Kashmir),
,, (,,) *niger* Waag.,
,, (,,) ,, , var. *devia* Reed,
,, (,,) ,, , var. *protracta* Reed,
,, (*Choristites*) cf. *gortanii* Heritsch, (species found in Alps),
Martinia semiglobosa Tschern. (found in the Urals),
Mentzelia naliensis Reed,
R. *Martiniopsis subpentagonalis* Waag.,
Squamularia (*Neophricodothyris*) *baralensis* Reed,
,, (,,) ,, , var. *suborbicularis* Reed,
R. *Spiriferina vercherei* Waag.
,, (*Spiriferellina*) *subcristata* Netsch. (found in Russia),
,, (,, ?) *zewanensis* Dien (found in the Zewan beds of Kashmir).
,, (,,) *æquiplicata* Reed,
R. *Athyris* (*Cleiothyridina*) *acutomarginalis* Waag.,
,, (,,) *semiconcava* Waag.,
,, ,,) ,, , var. *dokriensis* Reed,
,, (,,) ,, , var. *tumida* Reed,
,, (,,) ,, , var. *curta* Reed,
,, (,,) ,, , var. *medioplicata* Reed,
,, (,,) *roissyana* Keys. (a variable species, found in Russia and Spitzbergen),
,, (,, ?) *globulina* Waag.,
,, (,,) *epigona* (Abich) (found in Asia Minor),
,, (*Composita*) *globularis* Phill, var. *misriensis* Reed,
,, (,,) ,, , var. *crassa* Reed,
,, (,,) ,, , var. *naruensis* Reed,
R. *Spirigerella numismalis* Waag.
,, ,, , var. *longa* Reed,

Lamellibranchiata—
Parallelodon trimuensis Reed,
Sanguinolites (?) *sphenoidalis* Reed,
Girtypecten chitralensis (Reed),
* *Aphanaia salinaria* (Reed),
Pseudomonotis (*Claraia*) cf. *wangi* Patte ? (species found in Indo-China),
,, (*Aviculomonotis*) *indica* Reed,
Anodontophora conjungens (Waag.),
,, *purdoni* Reed,

Gastropoda—
Pleurotomaria (*Cyclites* ?) sp.,
Murchisonia (*Glyphodeta*) cf. *tschernyschewi* Jak. (a cast ; species found in Russia);
Meekospira cf. *acuminata* (Goldf.) (a cast ; species found in China).

Gastropoda—*contd.*
Loxonema sp.,
Soleniscus cf. *symmetricus* (King) (a cast; species found in Great Britain).
Strophostylus sargalensis Reed,
Euphemus carbonarius (Cox) (a well-known American species).
R. *Diaphorostoma indicum* (Waag.) (Waagen's "*Platystoma indicum*"),
R. *Warthia brevisinuata* Waag.,
Cephalopoda—
Tainoceras comptum Reed,
,, *debile* Reed,
,, *trimuense* Reed,
Pisces—
* *Helodopsis* sp.

Unrevised determinations.

Margaritina schwageri Zitt., var. (Amb beds),
Fusulina pailensis Schw. (Amb beds),
Polypora vermicularis Waag. and Pichl. (Amb beds),
Monotrypa mastoidea Waag. and Wentz. (Amb beds),
Orbipora ambiensis Waag. and Wentz. (Amb beds),
Stenopora hemisphœrica Waag. and Wentz. (Amb beds),
Amblysiphonella vesiculosa de Kon.,
Dybowskiella grandis Waag. and Wentz.,
Cyathocrinus indicus Waag.,
,, *kattaensis* Waag.,
Serpulites indicus Waag. (Amb beds),
Spirifer alatus Schloth.,
Cardiomorpha indica Waag.(horizon uncertain),
Dolabra arcina Waag.,
Aviculopecten crebristriatus Waag.,
Bucania kattaensis Waag.,
Aviculopecten crebristriatus Waag.,
Bucania kattaensis Waag.,
Euphemus lenticularis Waag.,
Helodopsis abbreviata Waag. (Amb beds),

Middle Productus Limestone.

Foraminifera—
* *Fusulina pailensis* Schw.
Bryozoa—
* *Polypora megastoma* de Kon.,
* ,, *ornata* Waag. and Pichl.,
* ,, *gigantea* Waag. and Pichl.,
* ,, *koninckiana* Waag. and Pichl.,
* *Hexagonella remosa* Waag. and Pichl.,
* *Araeopora remosa* Waag. and Wentz.,
* *Fistulipora parasitica* Waag. and Wentz.,
* *Amblysiphonella* sp.,
* *Dybowskiella* (*Fistulipora*) *grandis* (Waag. and Wents.).,
* *Geinitzella* (*Batostomella*) *columnaris* Schloth..,
* ,, ,, *crassa* Lonsd.,

Byvozoa—*contd.*
* *Stenopora ovata* Lonsd.?
* *Synocladia virgulacea* Phill.,
* *Fenestella jabiensis* Waag. and Pichl.,

Actinezoa—
* *Lonsdaleia* (*Waagenophyllum*) *indica* Waag. and Wentz.,
* ,, *virgalensis* Waag. and Wentz..
* ,, (*Wentzelella*) *salinaria* Waag. and Wentz.,
* *Michelinia indica* Waag. and Wentz.,

Vermes—
Serpulites indicus Waag.,

Crinoidea—
Poteriocrinus sp.,
Cyathocrinus sp.

Brachiopoda—
* *Lingula scrutata* Reed,
R. *Orthis janiceps* Waag.,
R. ,, ? *marmorea* Waag.,
,, (*Schizophoria*) *juresanensis* Tschern. (found also in Russia and Persia),
R. ,, (,,) *indica* Waag.,
R. ,, (,,) *derbyi* Waag.,
* ,, ,,) *subquadrata* Fliegel (found also in China),
,, (*Rhipidomella*) *corallina* Waag.,
R. ,, (,,) *incisiva* Waag.,
Enteletes subequivalvis Gemm., var. *rugata* Reed,
,, *singularis* Reed,
,, *conjunctus* Reed,
,, *socialis* Reed,
,, *waageni* Gemm. (an European species, found also in the Karakoram and the Himalaya (Chitichun).
,, *lamarcki* Fisch. de Waldh. (found in Russia and China),
,, (*Enteletina*) *acutiplicatus* Waag., var. *infrequens* Reed,
,, (,,) *pentameroides* Waag.,
Enteletoides redux Reed,
,, *tenuiplicatus* Reed.
Streptorhynchus pelargonatus Schloth. (found in Europe and China),
,, *mistus* Reed,
R. ,, *distortus* Waag.,
R. ,, *capuloides* Waag.,
R. ,, *memor* Reed,
,, (*Schuchertella*) *purdoni* Reed,
R. ,, ,, *semiplanus* Waag.,
Derbiya hemispherica Waag., var. *radiata* Reed,
,, (*Plicatoderbya*) *aemula* Reed,
R. ,, *grandis* Waag.,
R. ,, *regularis* Waag.,
Kiangsiella pectiniformis (Dav.) (originally "*Streptorhynchus pectiniformis*"),
,, ,, , var. *pauciplicata* Reed,
,, ,, , var. *fasciculata* Reed,
,, ,, , var. *lalesinuata* Reed,
,, *compressa* Reed.

Brachiopoda—*contd.*

Meekella ? *punjabica* Reed,
,, cf. *bashkirica* Tschern. (species found in Russia),
Rhynchotreta ? *dubia* Reed,
R. ,, ? *mansuyi* Reed,
Oldhamina decipiens (de Kon.) (found also in China),
Lyttonia nobilis Waag.,
Richthofenia lawrenciana (de Kon.), (found in other parts of Asia),
Productus (*Dictyoclostus*) *indicus* Waag.,
,, (,,) *tardatus* Reed,
,, (,,) *vishnu* Waag.,
,, (,,) *genuinus* Kut. (found also in Russia).
R. ,, (,,) *subcostatus* Waag.,
,, (,,) cf. *transversalis* Tschern. (species found in Russia),
,, (,,) cf. *gruenewaldti* Krot. (species found in Russia and China),
,, (*Sinuatella*) *celsus* Reed,
,, (,,) cf. *weyprechti* Toula (species found in Spitzbergen).
,, (*Plicatifera*) cf. *funiculatus* Mansuy (species found in Indo-China).
,, (*Linoproductus*) *lineatus* Waag.,
,, (,,) *aagardi* Toula, var. *implicata* Reed (probably found in Asia Minor),
,, (,,) cf. *lahuseni* Lich. (species found in Russia),
,, (,,) cf. *kulikii* Fred. (species found in Russia and Spitzbergen),
,, (*Ruthenia*) *purdoni* Dav., var., *circularis* Reed,
,, (,,) *vagans* Reed,
,, (*Waagenoconcha*) *humboldti* d' Orb., var. *dumosa* Reed (*forma typica* found in S. America).
R.* ,, (,,) *abichi* Waag.,
R. ,, (,,) ,, , var. *serialis* Waag.,
R. ,, (,,) ,, , var. *consors* Reed,
R. ,, (,,) ,, , var. *pseudotuberculata* Reed,
R.* ,, (,,) ,, , var. *densipustulata* Reed,
R. ,, (,,) ,, , var. *pseudo-palliata* Reed,
,, (*Buxtonia*) *cœlebs* Reed,
,, (*Juresania*) *scalaris* Mansuy, var. *semituberculata*, Reed,
,, (*Cancrinella*) *asperulus* Waag.,
,, (*Striatifera*) *mongolicus* Dien., var. *subcircularis* Reed,
,, (*Haydenella*) *kiangsiensis* Kays, var. *tumida* Waag.,
,, (,,) *vihianus* Dien., var. *salinaria* Reed,
,, (,,) *quæsitus* Reed,
,, (*Diaphragmus*) *fasciculatus* McChasn., var. *semicarinata* Reed.
,, (,,) ,, , var. *khasorensis* Reed,
,, (*Tschernyschewia*) *typicus* Stoy. (found in Armenia and Serbia).
,, (,,) ,, , var. *gemina* Reed,
,, (,,) *transindicus* Reed,
,, (,,) *vicinalis* Reed,
,, (,,) *parilis* Reed,
,, (,, ?) *mysius* (End.) (found in Asia Minor),
,, (,, ?) *fugax* (Reed) ("*Strophalosia fugax*"),
,, (,, ?) *punjabensis* Reed ("*Buxtonia punjabensis*").

Brachiopoda—*contd.*

Marginifera prænuntia Reed, var. *eremita* Reed,
,, *typica* Waag.,
,, ,, , var. *crassicostata* Reed,
,, *gratiosa* (Waag.),
R. ,, *ornata* Waag.,
R. ,, *ovalis* Waag.,
,, cf. *lebedewi* Tschern. (species found in the Urals),
,, cf. *jisuensis* Chao (species found in Mongolia),
,, cf. *morrisi* Chao (species found in Mongolia and the Caucasus and probably in the Himalaya (Chitichun)),
,, ? *ferox* Reed,

Strophalosia lamellosa (Gein.), var. *linearis* Reed,
,, *excavata* (Gein.), var. *remota* Reed,
R. ,, *indica* Waag.,
* ,, *rarispina* Waag.,

Leptalosia cf. *ovalis* Dunb. and Cond. (species found in the Pennsylvanian of America),

Aulostegee wangenheimi de Vern., var. *punjabica* Reed,
* *Chonetes deplanata* Waag.,
* ,, *strophomenoides* Waag.,
,, (*Chonetina*) *dalmiriensis* Reed,
,, (,,) *semiovalis* Waag.,
,, (*Dienerella*) *dichotoma* Waag., var. *bilotensis* Reed,
,, (,,) *dichotoma*, var. *pluriplicata* Reed,
R. ,, (,,) *squamulifera* Waag.,
R. ,, (,,) *æquicosta* Wagg.,
* ,, (,,) *grandicosta* Wagg., var. *biplex* Reed,
,, (*Lissochonetes*) *geinitzianus* Wagg. (="*Ch. glaber*" Gein., *non* Hall),

R. ,, (,, ?) *morahensis* Wagg.,
Chonetella nasuta Wagg.,
,, ? *indica* Wagg.,
Pugnax (*Wellerella*) *sexatilis* (Reed), ("*Camarophoria nucula*, var. *sanatilis*"),
,, (,,) ,, , var. *salaria* Reed,
,, (,,) *naliensis* Reed,
Uncinunellina theobaldi (Wagg.), ("*Rhynchonclla* (*Uncinulus* ?) *theobaldi*"),
,, *jabiensis* (Wagg)., ("*Rhynchonella* (*Uncinulus* ?) *jabiensis*")
R. ,, *postera* (Wagg.),
Uncinuloides diffissa Reed,
,, *imitatrix* Reed (possibly eqivalent to a form found in Indo-China),
Rhynchopora nikitini Tschern., var. *scorsa* Reed (*forma typica* found in Russia, Spitzbergen and Bolivia),
,, ? *wynnei* Wagg.,
,, ? *complanata* Reed,

Camarophoria purdoni Dav.,
,, *mutabilis* Tschern. (found in Russia and China),
,, *schlotheimi* V. Buch, var. *vagata* Reed (*forma typica* found in Europe),
,, *biplicata* Stuckenb, (found in Russia),
R. ,, *pinguis* Wagg.,
,, *humbletonensis* Howse, var. *divisa* Reed,
,, cf. *netschajewi* Tschern., (species found in Russia),
,, cf. *hofmanni* (Krot.), (species found in Russia),
,, cf. *applanata* Tschern, (species found in Russia),

Brachiopoda—*contd.*
Camarophoria cf. *tanankouensis* Ozaki (species found in Manchuria),
,, cf. *thevenini* Kozl. (species found in Bolivia and Texas),
,, (*Lævicamera*) *sella* Kut., var. *preacuta* Reed,

Terebratuloidea *ornata* Waag.,
,, ,, , var. *uniplicata* Reed,
,, *davidsoni* Waag.,
,, *trifida* Reed,
,, *depressa* Waag., var. *daudensis* Reed,
R. ,, *minor* Waag.,
Dielasma bakhense Reed,
,, *nexile* Reed,
,, *plica* (Kut.), var. *arcuata* Reed,
,, *truncatum* Waag., var. *misrikhanensis* Reed,
R. ,, *acutangulum* Waag.,
,, ,, , var. *subcuneata* Reed,
R. ,, *guttula* Waag.,
,, *nummulus* Waag.,
,, *sultanense* Reed,
,, cf. *darvasicum* Tschern. (species found in Central Asia),
,, ? *ovoidale* Reed,
,, (*Heterelasma*) *problematicum* (Waag.),
,, (,,) *biplex* Waag., var. *protracta* Reed,
,, (,,) ,, , var. *pumila* Reed,
Notothyris *duplicata* Reed,
,, *buriensis* Reed,
,, *lucida* Reed,
,, *ghundiensis* Reed,
,, *prælecta* Reed,
,, ,, , var. *acuta* Reed,
,, *fissicostata* Reed,
,, *gojrænsis* Reed,
,, *warthi* Waag., var. *crscsa* Reed,
,, *inflata* Waag., var. *bisecta* Reed,
,, *lochardi* Mansuy, var. *oviformis* Reed (*forma typica* found in Indo-China),
,, *inæquiplicata* Reed,
,, *sarinensis* Reed,
,, *djoulfensis* (Abich) (a Caucasus species),
,, ? *riparia* Reed,
R. ,, *simplex* Waag.,
R. ,, *subvesicularis* (Dav.)
R. ,, *lenticularis* Waag.,
Dielasmina crassiplicata Reed,
,, *gravida* Reed,
,, *globosa* Reed,
,, *peregrina* Reed,
,, *extensa* Reed,
R. ,, *plicata* Waag.,
Gefonia ? *emerita* (Reed), ("*Notothyris mediterranea*, var. *emerita*"),
,, ? *bifrons* Reed,

Brachiopoda—*contd.*

Hemiptychina sparsiplicata Waag (? a variety of *H. himalayensis* Dav.) ;
,, *himalayensis* (Dav.), var. *mediosulcata* Reed (*forma typica* found in the Himalaya)
,, ,, , var. *lata* Reed,
,, *warchensis* Reed, var. *pyriformis* Reed,
,, *truncata* Reed,
,, ,, , *banschangensis* Reed,
,, *morrisi* Grabau (found in Mongolia),
,, *patula* Reed,
,, ? cf. *schellowieni* Gort. (species found in the Carnic Alps),
,, *crebriplicata* Waag.,
Hustedia grandicosta (Dav.),
,, ,, , var. *subcircularis* Reed,
,, ,, , var. *elongata* Reed,
,, *indica* Waag., var. *chittidilensis* Reed,
,, ,, , var. *interplicata* Reed,
,, *rhynchospiroides* Reed,
* *Cardinocrania indica* Waag.,
Spirifer (*Neospirifer*) *musakheylensis* Dav. (a widely spread type, scarcely separable from *Sp. fasciger* Keys ; found in Kashmir, Spiti, Chitral, Garhwal, Kumaon, Karakoram, Sikkim, Indo-China, Rotti, Timor and Tibet.),
,, (*Neospirifer*) *musakheylensis* var. *humilis* Reed,
,, (,,) *warchensis* Reed, var. *scabrosa* Reed,
,, (,,) *sodalis* Reed,
,, (,,) *cameratus* Mort., var. *externa* Reed (*forma typica* found in the United States and Brazil).
* ,, (,, ?) *oldhamianus* Waag.,
,, (*Elivina*) *blasii* de Vern., var. *semiovalis* Reed,
,, (,,) *wynnei* Waag. (*pars*),
,, (*Purdonella*) *lunwalensis* Reed,
,, (,,) *multiradiatus* Reed,
,, (,,) *limitaris* Reed,
,, (,,) *conformis* Reed,
R. *Uncinella indica* Waag.,
Martinia acutomarginalis Dien. (found also in the Himalaya (Chitichun),
,, *buriensis* Reed,
,, *uralica* Tschern, var. *longa* Tschern. (found also in the Urals, Central Asia, China and the Karakoram),
R. ,, *semiplana* Waag.,
* ,, ,, , var. *radiata* Reed,
R. ,, *warthi* Waag.,
R. ,, *elongata* Waag.,
* ,, ,, , var. *sinuata* Reed,
R. ,, *chidruensis* Waag.,
* ,, *elegans* Dien., var. *particeps* Reed,
,, cf. *triquetra* Gemm. (species widespread in Europe and Asia),
,, (*Ella*) *blanfordi* Reed,
Mentzelia punjabica Reed,
,, *naliensis* Reed,

R. *Squamularia* (*Neophricodothyris*) *asiatica* Chao (Waagen's "*Reticularia lineata*" (*pars*) : (found in several parts of Asia, and in Nova Zembla),
,, (*Neophricodothyris*) *waageni* (Loczy), var. *subquadrata* Reed,
,, (,,) *nummulina* Reed, ("*Reticularia indica* Waag."),
,, (,,) *bilotensis* Reed,
,, (,,) *attenuata* Reed,
R. ,, (,,) *elegantula* (Waag.) ("*Reticularia elegantula*"),
R. ,, (,,) *indica* (Waag.) ("*Reticularia indica*"),
,, (,,) cf. *pulcherrima* (Gemm.) (the species occurs in the Himalaya (Chitichun)),
,, (,,) cf. *caroli* (Gemm.) (species found in Asia Minor).
,, (,,) cf. *frechi* "Renz",

Spiriferina (*Spiriferellina*) *cristata* Schl., var. *commixta* Reed (*forma typica* abundant and variable),
,, (*Spiriferellina*) *bilotensis* Reed,
,, (,,) ,, , var. *curta* Reed,
,, (,, ?) *nasuta* Waag.,
,, (,, ?) *panderi* Moll., var. *buriensis* Reed (species found in the Urals and Timans),
,, (*Mansuyella*) *ornata* Waag.,
,, (,,) cf. *holzapfeli* Tschern. (species found in the Urals, the Timan and Spitzbergen),
,, (*Reticulariina*) *transindica* Reed,
,, (*Paraspiriferina*) *ghundiensis* Reed,
,, (,,) *punjabensis* Reed,

Athyris (*Cleiothyridina*) *capillata* Wagg.,
,, (,,) ,, , var. *subcarinata* Reed,
,, (,,) ,, , var. *pinguis* Reed,
,, (,,) ,, , var. *tripartita* Reed,
,, (,,) ,, , var. *sacculus* Reed,
,, (,,) ,, , var. *tenuis* Reed,
,, (,,) *xetriformis* Reed,
,, (,,) *pectinifera* (Sow.) ("*Athyris royssii*" (*pars*),
,, (,,) ,, , var. *venusta* Reed,
,, (,,) *dalmiriensis* Reed,
R. ,, (,,) *subexpansa* Waag.,
,, (,,) *simulans* Reed,
,, (,,) *accola* Reed ("*Athyris capillata*" (*pars*),
,, (,,) *saraiensis* Reed,
,, (,, ?) cf. *bajtuganensis* Netsch., (species found in N. Russia).
,, (*Composita*) *protea* (Abich), var. *complanata* Reed,
,, (,,) ,, , var. *parilis* Reed,
,, (,,) ,, , var. *subalata* Reed,
,, (,,) ,, , var. *inflata* Reed,
,, (,,) ,, , var. *patula* Reed,
,, (,,) *indosinensis* Mansuy (found in Indo-China),
,, (,,) *globularis* Phill., var. *misriensis* Reed (probably identical with a form from China).
,, (,,) ,, , var. *crassa* Reed,
,, (,,) ,, , var. *naruensis* Reed,
R. ,, (,,) *grossula* Waag.,

Brachiopoda—*contd.*
Spirigerella timorensis (Rothpl.) (“ *Sp. grandis* ” (*pars*) ; found in Timor)
,, ,, , var. *semisinuata* Reed,
,, *grandis* Waag., var. *obesa* Huang,
,, *gigas* Reed,
,, *proxima* Reed,
,, *obovata* Reed,
,, ,, , var. *selliformis* Reed,
R. ,, *derbyi* Waag.
,, ,, , var. *subpentagonalis* Reed,
* ,, ,, , var. *acutiplicata* Waag.,
,, *discors* Reed,
,, *minuta* Waag.,
R. ,, *hybrida* Waag.,
R. ,, *media* Waag.,
R. ,, *fusiformis* Waag.,
,, cf. *pertumida* Dien. (species found in the Himalaya (Chitichun) and possibly Bolivia).

Lamellibranchiata—

Schizodus dubiiformis Waag.,
Cypricardella trapezoidalis Reed,
Edmondia cf. *gümbeli* Gemm. (European species),
R. ? *Allorisma pleuromyoides* Waag.,
,, cf. *yachihoensis* (Grabau) (species found in the early Permian of China).
Procrassatella sp.,
Aviculopecten expositus Reed,
,, *regularis* Reed,
,, *ruklensis* Reed,
,, *punjabensis* Reed.
* ,, *præcox* Waag.,
* ,, *prototextorius* Waag.?,
* ,, *nodulifer* Reed,
,, cf. *netschajewi* Lich., (species found in the Urals and Timan Mts.),
* ,, aff. *subfimbriatus* de Vern. (Russian species).
Pterinopecten (*Dunbarella*) *warchensis* Reed,
Pernopecten salarius Reed,
Blanfordinia lunwalensis Reed,
,, *fraterna* Reed,
,, *trifurcata* Reed,
,, *cardiiformis* (Reed),
Limatulina cf. *krotovi* (Stuckenb.) (Russian species),
Pseudomonotis (*Eumorphotis*) *nodulata* Reed,
,, (*Aviculomonotis?*) *waageni* Reed,
Myalina banschangensis Reed,
Atomodesma semiplicata Reed,
Plethomytilus lineatus Reed,
R. *Lithodomina abbreviata* Waag.,

Gastropoda—
Pleurotomaria (*Pnymatopleura*) *baccata* Reed,
,, (*Plocostoma*?) *punjabica* Waag.,
,, (*Gosseletina*) cf. *wanneri* Haml. (a Timor species),
,, (*Trepospira*) aff. *hunica* Dien. (species found in the Himalaya),
Murchisonia (*Stegocoelia*) cf. *quinquecostata* Yin, (Chinese species),
Naticopsis (*Neritomopsis*) *ambiensis* Reed,
R. *Euomphalus pusillus* Waag.,
,, (*Schizostoma*) *oldhami* Reed,
Provermicularia? cf. *latispira* (Grabau) (species found in China),
R. *Diaphorostoma*? (*Platystoma*) *indicum* (Waag.),
Bellerophon cf. *vigilii* Stache (identical with a Himalayan form; species found in the Tyrol).
R. ,, *blanfrodianus* Waag.,
R. ,, *jonesianus* Waag.,
R. ,, *affinis* Waag.,
R. ,, *triangularis* Waag.,
R. *Euphemus indicus* Waag.,
R. ,, *apertus* Waag.,
R. ,, *lævis* Waag.,
R. *Warthia polita* Waag.,

Cephalopoda—
* *Nautilus* ? aff. *wanneri* Han. (a Timor species),
Metacoceras chittidilense Reed,
* ,, (*Taenionautilus*) *multicostatum* (Reed) ("*Foordiceras transitorium*, var. *multicostata*"),
Foordiceras goliathus ‘Waag’. ("*Nautilus goliathus*"),
Pseudometacoceras grypoceroides (Reed) ("*Foordiceras grypoceroides*"),
Pselioceras convolutum (Waag.), ("*Nautilus convolutus*"),
Paranautilus peregrinus (Waag.) ("*Nautilus peregrinus*"),
Liroceras bakhense Reed,
R. *Stearoceras immane* (Reed) ("*Coloceras immane*"),
R. *Gyroceras medlicottianum* Waag.,
Palæolecanites chapriensis Reed,
Ophiceras ? *bilotense* Reed,
Xenaspis carbonaria Waag.,
Paraceltites sp.

Unrevised determinations—
Steinmannia gemina Waag. & Wentz.,
Amblysiphonella vesiculosa Waag. & Wentz.,
,, *radicifera* Waag. & Wentz.,
,, *multilamellosa* Waag., & Wentz.,
,, *socialis* Waag. & Wentz.,
Circopora faveolata Waag. & Wentz.,
,, *tubulosa* Waag. & Wentz.,
Irregulatopora undulata Waag. & Wentz.,
Disjectopora milleporæformis Waag. & Wentz.,
Carterina pyramidata Waag. & Wentz.,
Hexagonella tortuosa Waag. & Wentz.,
,, *laevigata* Waag. & Wentz.,

Unrevised determinations—*contd.*
Amplexus cristatus Waag. & Wentz.,
Lonsdaleia wynnei Waag. & Wentz.,
Michelinia indica Waag. & Wentz.,
,, cf. *glomerata* M'Coy,
Araeopora tuberosa Waag. & Wentz.,
Philocrinus cometa de Kon.,
Poteriocrinus spp.,
Cyathocrinus goliathus Waag.,
,, *virgalensis* Waag.,
Eocidaris forbesiana de Kon.,
Spirorbis helix King,
Dybowskiella expansa Waag. & Wentz.,
Rhombopora obliqua Waag.,
Acanthocladia anceps Schl.,
Thamniscus dubius Schl.,
,, *serialis* W. & T.,
Goniacladia indica W. & T.,
Phyllopora haimeana de Kon.,
Polypora sykesi, de Kon.,
,, *transiens* W. & T.
Fenestella perelegans Meek,
Spirifer (*Neospirifer*) *oldhamianus* Waag.,
Streptorhynchus deltoideus Waag.,
Derbya vercherei Waag.,
Chonetes compressa Waag. (horizon uncertain),
Rhynchonella? morahensis Waag.,
Oxytoma atavum Waag. (horizon doubtful; probably = *Blanfordinia cardieformis* Reed),
Pleurophorus subovalis Waag.,
Nucula trivialis Eichw.,
Macrodon (*Parallelodon*) *geminum* Waag.,
Pseudomonotis garforthensis King,
,, *gigantea* Waag.,
Aviculopecten morahensis Waag.,
Euomphalus parvus Waag.,
Warthia lata Waag.,
Nautilus (*Metacoceras*) *flemingianus*
,, (*Pselioceras?*) *connectens* Waag. (horizon uncertain—*Middle or upper*)
Orthoceras punjabiense Waag.
Xystracanthus gracilis Waag.,

Psammodus sp. (from Kafir Kot),
Psephodus depressus Waag.,
Poecilodus paradoxus Waag.,

Upper Productus Limestone.

Bryozoa—
* *Polypora megatoma* de Kon.,
* *Stenopora ovata* Lonsd.,
* *Dybowskiella grandis* Waag. and Wentz.

Vermes—
Spirorbis helix King.

Brachiopoda—
Orthis (*Schizophoria*) *juresanensis* Tschern.,
Orthotichia sulcata Reed,
Enteletes waageni Gemm.,
* ,, (*Enteletina*) *sublaevis* Waag.,
Enteletoides tenuiplicatus Reed.
Streptorhynchus (*Schuchertella*) *asperulus* Reed,
* ,, ,, *semiplanus* Waag.,
R. *Derbyia hemispherica* Waag.,
,, ,, , var. *scutalis* Reed,
,, *subaurita* Reed,
,, *subsinuata* Reed,
* ,, *altestriata* Waag.,
R. ,, *grandis* Waag.,
R. ,, *regularis* Waag.,
R. ,, (*Plicatoderbya*) *plicatella* Waag.,
Meekella cf. *eximiaeformis* 'Toula' (greatly resembling a form from the Barents Islands species found in Nova Zembla),
Lyttonia nobilis Waag.,
Richthofenia lawrenciana (de Kon.),
Productus (*Dictyoclostus*) *indicus* Waag.,
,, (,,) ,, , var. *paucicostata* Reed,
,, (,,) ,, , var. *subvexa* Reed,
,, (,,) *uralicus* Tschern. (species found in Russia, various parts of China Indo-China and Chitral),
R. ,, (,,) *subcostatus* Waag.,
,, (,,) *yangtzeensis* Chao, var. *adumbrata* Reed,
,, (,,) ,, , var. *tumefacta* Reed,
,, (,,) *craticulatus* Reed ,var. *defossa* Reed,
,, (,,) *aratus* Waag.,
,, (,,) *genuinus* Kut.,
,, (,,) cf.*inca* d' Orb. (species found in Bolivia and Persia).
,, (*Linoproductus*) *lineatus* Waag.,
,, (,,) ,, , var. *sirrensis* Reed,
,, (,,) *cora* d' Orb., var. *superba* Reed (probably found in Indo-China, Bolivia, Samara and the N. Caucasus),
,, (,,) *simensis* Tschern., var. *abrupta* Reed,
,, (*Ruthenia*)*purdoni* Dav.,
,, (,,) ,, , var. *paraliensis* Reed,
,, (,,) ,, , var. *prolongata* Reed,
,, (,,) ,, , var. *castrensis* Reed,
,, (,,) *irginae* Stuck ,var. *aliena* Reed (probably identical with a form found in Bolivia),
,, (*Waagenoconcha*) *humboldti* d'Orb., var. *silveana* Stuck (probably equivalent to form found in Russia),
,, (,,) *humboldti*, var. *xenia* Reed,
,, (,,) ,, , var. *conjuncta* Reed,
R. ,, (,,) *serialis* Waag.,
R. ,, (,,) *abichi* Waag.,
,, (,, ?) *cylindricus* Waag.,
,, (,, ?) ,, , var. *discreta* Reed,
,, (*Avonia*) *opuntia* Waag. (found in Timor),
,, (*Tschernyschewia*) *vicinalis* Reed,

Brachiopoda—*contd.*
Marginifera banschangensis Reed,
,, *gratiosa* (Waag.),
R. ,, *typica* Waag.,
R. ,, *ornata* Waag.,
Strophalosia lamellosa (Gein.), var. *linearis* Reed,
,, *blanfordi* Reed,
,, *salmunensis* Reed,
R. ,, *indica* Waag.,
Chonetes squama Waag.,
,, (*Plicochonetes*) *pœckelmanni* de Terra, var. *buriensie* Reed.
,, (*Paeckelmannia*) cf. *ambiensis* Waag.,
R. ,, (*Lissochonetes*) *morahensis* Waag.,
R. ,, (,,) *avicula* Waag.,
Chonetella nasuta Waag.,
Uncinuloides imitatrix Reed,
Rhynchopora relegata Reed,
Camarophoria purdoni Dav.,
,, *mutabilis* Tschern.,
,, *cuneiformis* Reed,
,, *schlotheimi* v. Buch, var. *vagata* Reed,
,, *waageni* Netsch. ("*C. superstes* Waag., *non* de Vern."),
,, *irregularis* Reed,
Notothyris buriensis Reed,
,, *prælecta* Reed,
,, *warthi* Waag., var. *crassa* Reed,
,, *revocata* Reed,
R. ,, *multiplicata* Waag.,
R. *Terebratuloidea pinguis* Waag.,
Hemiptychina sparsiplicata Waag., var. *intermedia* Reed,
,, *himalayensis* (Dav.), var, *obligata* Reed,
,, *truncata* Reed, var. *elongata* Reed,
Cryptacanthia indica Reed,
,, ,, , var. *lata* Reed,
Spirifer (*Neospirifer*) *musakheylensis* Dav.,
,, (,,) *warchensis* Reed,
,, (,,) ,, , var. *scabrosa* Reed,
,, (,,) *ravana* Dien., var. *plicatifera* Reed (*forma typica* found in the Productus shales of the Himalaya),
,, (,,) *cameratus* Mort., var.
,, (,,) cf. *dunbari* R. H. King,
,, (*Elivina*) *interplicatus* Rothpl., var. *bashkirica* Tschern. (found in Russia, Greenland, the Camic Alps and probably Manchuria).
,, (,,) *blasii* de Varn., var. *semiovalis* Reed,
,, (*Choristitella*) *internatus* Reed,
,, (*Purdonella*) *limitaris* Reed,
,, (,,) *conformis* Reed,
Martinia acutomarginalis Dien., var. *crenata* Reed,
,, *subrhomboidalis* Reed,
,, *corculum* (Kut.) (a variable species, found in China and probably the Himalayas (Chitichun)),

Brachiopoda—*contd.*
R. *Martinia warthi* Waag.,
R. ,, *semiplana* Waag.,
R. ,, *chidruensis* Waag.,
R. ,, *elongata* Waag.,
,, cf. *kraffti* Bittn. (a central Asian species).
,, (*Ella*) *simensis* Tschern., var. *substricta* Tschern. (found in the Urals and Timan Mts.)
,, (,,) *blanfordi* Reed,
,, (*Fredericksia*) *khurensis* Reed,
Mentzelia? *salaria* Reed,
R. *Squamularia* (*Neophricodothyris*) *indica* Waag. ("*Reticularia indica*"),
,, (,,) *spatulata* Reed,
,, (,,) *inaequilateralis* Gemm. (found in Italy, China and Indo-China).
Spiriferina (*Spiriferellina*?) *panderi* Möll., var. *buriensis* Reed,
,, (*Mansuyella*) cf. *margaritae* Gemm. (species recorded in the Himalaya (Chitichun)).
Athyris (*Cleiothyridina*) *capillata* Waag.,
,, (,,) *pectinifera* (Sow.) ("*Athyris royssii*" (*pars*)),
,, (,,) ,, , var. *venusta* Reed,
,, (,,) *dalmiriensis* Reed,
,, (,,) *gerardi* Dien. (found in the Himalaya and the Urals),
,, (,,) *interposita* Reed ("*Athyris royssii*" (pars)).
,, (,,) *warchensis* Reed,
,, (,,) *accola* Reed,
R. ,, (,,) *subexpansa* Waag.,
R. ,, (,,) *ambiguaeformis* Waag.,
,, (*Composita*) *protea* (Abich), var. *complanata* 'Reed.'
Spirigerella timorensis (Rothpl.),
,, *grandis* Waag.,
,, ,, , var. *elongata* Reed,
,, *proxima* Reed,
,, *obovata* Reed,
R. *Spirigerella derbyi* Waag.,
,, ,, , var. *compressa* Reed,
R. ,, *praelonga* Waag.,
,, ,, , var. *carinata* Reed,
,, *paraliensis* Reed,
R. ,, *alata* Waag.,
R. ,, *media* Waag.,
R. ,, *hybrida* Waag.,

Lamellibranchiata—
R. *Allorisma perelegans* Waag.,
R. *Lucina*? *progenetrix* Waag.,
R. ,, ? *bombifrons* Waag.,
R. *Loripes*? *atavus* Waag.,
R. ,, ? *proavius* Waag.,
R. *Gouldia* ? *primaeva* Waag.,
R. *Septifer squama* Waag.,
Parallelodon respectus Reed,
,, cf. *subtilistriatus* Wanner (a cast; species found in Timor),

Lamellibranchiata—*contd.*

Nuculopsis cf. *anthraconeiloides* Chao (a Chinese species),
Palaeoneilo ? *centralis* Reed,
R. *Myophoria* ? *subelegans* Waag.,
R. *Schizodus cardissa* (Waag.), (" *Myophoria cardissa* "),
R. ,, *pinguis* Waag.,
R. ,, *rotundatus* Brown.? (a British species),
R ,, *praecox* (Waag.) (" *Myophoria praecox* "),
,, *emarginatus* Reed (probably=*Sch. rotundatus* Waag., *non* Brown),
,, *wheeleri* (Swallow) (probably identical with forms from Russia, central Asia and Greenland),
R. *Astarte* ? *ambiensis* Waag.,
Astartella consimilis Reed,
,, *permocarbonica* Tschern. (found in Russia and the Carnic Alps),
Palaeolucina cf. *carbonaria* Chao (A Chinese species),
Pleurophorina complanata (Waag.) (" *Pleurophorus complanatus* "),
* ,, *imbricata* (Waag.) (" *Pleurophorus imbricatus* "),
Lithophagus cf. *permianus* Frebold (a Greenland species),
Lithodomina bakhensis Reed,
Solemya biarmica de Vern. (typical of the Permian in E. Russia and Germany and found in this Himalayan Kuling Shales),
R. *Pseudomonotis gigantea* Waag.,
* ,, *middlemissi* Dien.,
,, (*Aviculomonotis*) *indica* Reed, var. *intercostata* Reed,
,, (,,) *waageni* Reed,
Aviculopecten wynnei 'Waag' var.
,, *squamiger* Reed,
R. ,, *granosus* Waag.,
R. ,, *derajatensis* Waag.,
R. ,, *katwahiensis* ? Waag.,
Pecten (*Entolium*) *aviculatus* (Swallow) (found in China and probably Kashmir),
Blanfordinia lunwalensis Reed,
,, *cardiiformis* (Reed) (" *Oxytoma* (?) *atavum*. var. *cardiiformis* "),
,, ? *subexotica* Waag.,
Limatulina propinqua Reed,
Liebea sacculus Reed,

Gastropoda—

Pleurotomaria (*Phymatopleura*) *paraliensis* Reed,
,, (,,) *uchhaliensis* Reed,
,, (*Baylea*?) *durga* Waag.,
,, (,, ?) *sequens* Waag.,
,, (,, ?) cf. *kirillowensis* Lich. (a Russian species),
,, (*Ptychomphalina*) *banschangensis* Reed,
,, (*Plocostoma*) *conglobata* Wanner (found also in Timor),
Tretospira indica Reed,
,, *funiculata* Reed,
Murchisonia (*Goniasma*) *conjungens* Waag.,
Hemizyga (*Plocezyga*) *indica* Reed,
Pseudozygopleura aff. *semicostata* Meek (species found in the Pennsylvanian of the United States),
Anomphalus ? *priscus* (Waag.), (" *Margerita prisca* "),

Gastropoda—*contd.*
Macrocheilinia (*Sphaerodoma*) *avellanoides* (de Kon.) (probably synonymous with *Soleniseus mucronatus* Yin from China),
,, (,,) *primigenia* (Conr.),
,, (,,) *verisimilis* Reed,
,, (,,) cf. *brevis* White (species found in N. America and China).
,, (,,) cf. *ventricosa* (Hall) (species found in N. America and China),
,, (,,) cf. *intercalaris* (Meek and Worthen) (an American species),
Auriptygma khairliense Reed,
Naticopsis spectata Reed,
R. ,, *khurensis* Waag.,
R. ,, (*Neritomopsis*) *arenicola* (Waag.), ("*Phasianella arenicola*"),
* ,, (,,) *ovula* Waag.
Ianthinopsis oviformis Reed,
Orthonychia abundans (Wanner) (a variable species, found in Timor),
R. *Euomphalus pusillus* Waag.,
Bellerophon equivocalis Reed
,, *khairliensis* Reed,
,, *acuticarinatus* Yin, var. *advena* Reed (probably identical with forms found in China and Greenland),
R. ,, *blanfrodianus* Waag.,
R. ,, *jonesianus* Waag.,
R. ,, *orientalis* Waag.,
R. ,, *affinis* Waag.,
R. ,, *squamatus* Waag.,
R. ,, *impressus* Waag.,
R. ,, *triangularis* Waag.,
,, (*Tropidocyclus*) *punjabicus* Reed,
R. *Mogulia regularis* Waag.,
R. *Stachella semiaurita* Waag.,
R. ,, *bifrons* Waag.,
R. *Warthia polita* Waag.,
R. *Bucania angustifasciata* Waag.,
R. ,, *integra* Waag.,
R. *Euphemus indicus* Waag.,
R. ,, *laevis* Waag.,
R. ,, *apertus* Waag.,
Euphemus? cf. *baroghilensis* (Reed),

Scaphopoda—
Plagioglypta herculea (de Kon.), ("*Entalis herculea*") (found in Asia Minor, the United States (Texas)),

Cephalopoda—
* *Tainoceras noetlingi* Frech, var *subglobosa* Reed,
* *Huanghoceras warchense* (Reed), ("*Metacoceras warchense*").
Metacoceras (*Taenionautilus*) *wynnei* (Waag.) ("*Nautilus wynnei*").
Parametacoceras venustum Reed,
Temnocheilus multituberculatus (Waag.) ("*Nautilus multituberculatus*"),
,, cf. *grewingki* Tschern. (species found in Russia).
Coelonautilus sp.,

Cephalopoda—*contd.*
Pselioceras (?*Apheleceras*) *ophioneum* (Waag.) ("*Nautilus ophioneus*"),
Solenocheilus buriensis Reed.
Liroceras bakhense Reed.
Planetoceras postremum Reed,
Stearoceras punjabicum Reed,
R. ,, *immane* (Reed) ("*Nautilus* (*Coloceras*) *immanis*").
Gastrioceras noduliferum Reed,
Cyclolobus cf. *walkeri* Dien. (species found in the Himalaya (Chitichun) and Madagascar).
Eumedlicottia primas (Waag.) ("*Sageceras primas*"),
Episageceras wynnei (Waag.) ("*Sageceras wynnei*"),
Xenodiscus plicatus Waag.

Pisces—
Helicoprion sp.

Unrevised determinations—
Margaritina schwageri Zitt.,
Lingulina decipiens Schw.
Fusulinella waageni Schw.
Steinmannia salinaria Waag. & Wentz.,
Dybowskiella expansa Waag. & Wentz.,
Hexagonella ramosa Waag. & Wentz.,
Stenopora chaetetiformis Waag. & Wentz.,
,, *nicholsoni* Waag. and Wentz.,
Rhombopora polyporata Waag.,
Geinitzella columnaris Schl.
Synocladia virgulacea Phill.,
Polypora koninckiana Waag. and Pichl.,
,, *biarmica* Keys.
,, *ornata* Waag. and Pichl.,
Fenestella jabiensis Waag.,
Thamniscus serialis Waag. and Pichl.,
Michelinia placenta Waag. and Wentz.,
,, *abichi* Waag.,
Amplexus abichi Waag. & Wentz.,
Pachypora curvata Waag. and Wentz.,
,, *jabiensis* Waag. and Wentz.,
Lonsdaleia (*Waagenophyllum*) *indica* Waag. and Wentz.,
Araeopora ramosa Waag. and Wentz.,
Phyllopora jabiensis Waag. and Wentz.,
,, *cribellum* de Kon.,
Poteriocrinus sp.,
Cyathocrinus goliathus Waag.,
Spirorbis helix King.
Cardinocrania indica Waag. (perhaps the young of a species of *Richthofenia*).
Camarophoria globulina Phill.,
Chonetes trapezoidalis Waag.,
,, *tripartita* Waag.,
Spengleria vetusta Waag.,
Eucharis grandaeva Waag.,
Allorisma dubium Waag.,

Unrevised determinations—*contd.*
Palanatina ("*Palanatina*") *indica* Waag.,
Sphaeriola grandaeva Waag.,
Pleurophorus acuteplicatus Waag.,
Cleidophorus trapezoidalis Waag.,
,, *striatulus* Waag.,
Schizodus compressus Waag.,
Nuculana subacuta Waag.,
Nucula ventricosa Hall,
,, *trivialis* Eichw.,
Dolabra corbina Waag.,
Lithodomus atavus Waag.,
Modiola transparens Waag.,
Atomodesma indicum Waag.,
Pseudomonotis radialis Phill.,
,, *deplanata* Waag.,
Avicula chidruensis Waag.,
Aviculopecten jabiensis Waag.,
,, *pseudoctenostreon* Waag.,
,, *squamula* Waag.,
Pecten praecox Waag.,
Euchondria subpusilla Waag.,
Lima footei Waag.,
Holopella trimorpha Waag.,
Bucania ornatissima Waag.,
Macrotheca wynnei Waag. (horizon uncertain),
Arcestes (*Popanoceras*) *priscus* Waag.,
Nautilus (*Holconautilus*?) *latissimus* Waag.,
,, (*Pselioceras* ?) *connectens* Waag. (uncertain whether Middle or Upper)
Orthoceras obliqueannulatum Waag.,
Cythere cf. *elongata* Münst.,
Xystracanthus gracilis Waag.,
,, *major* Waag.,
Helodopsis elongata Waag.,
Psephodus indicus Waag.,
Cyclolobus oldhami Waag.,
Petalorhynchus indicus Waag.,
Xystracanthus giganteus Waag.,
Thaumatacanthus blanfordi Waag.,

Precise Horizon Uncertain.

Lower or base of middle—
Orthis (*Perditocardinia*) *uralica* Tschern., var. *subelongata* Reed,
Dielasma perangustum Reed,
,, *redux* Reed,
,, *hochstetteri* Toula, var. *disbrepans* Reed,
,, *purdoni* Reed,
,, cf. *ellipticum* Netsch.,
,, cf. *curvatum* Tschern.,
Hemiptychina subequalis Reed,
Aviculopecten (*Euchondria*) *sortilus* Reed.

Lower or middle—

Derbyia sultanensis Reed,
Productus (*Ruthenia?*) *subpalliatus* Reed,
,, (*Tschernyschewia*) *mysius* End., var. *bakhensis* Reed,
Chonetes (*Plicochonetes*) *simulata* Reed,
Hemiptychina cf. *pseudoelongata* Schellw.,
Squamularia (*Neophricadothyris*) *oviformis* Reed,
Athyris (*Composita*) *semirostrata* Reed,
Allorisma waageni Reed,
Sphenotus cataractus Reed,
Palæocorbula dubia Reed,
Aviculopecten misrikhanensis Reed,
Anomia ? sp.,
Pleurotomaria (*Worthenia*) cf. *orientalis* Roem.,
,, (*Trepospira?*) cf. *chitralensis* Reed,
Naticopsis sessilis Reed,
Bellerophon cf. *subcostatus* Fliegel,

Middle or base of upper—

Enteletes laevissimus Waag.,
Kiangsiella pectiniformis (Dav.), var. *fissicostata* Reed,
Richthofenia sinensis Waag.,
Productus (*Ruthenia*) *purdoni* Dav., var. *mirkalanensis* Reed,
,, (*Juresania*) *juresanensis* Tschern.,
,, (*Striatifera*) *compressus* Waag., var. *corniformis* Chao (a Chinese variety),
Notothyris daudensis Reed,
Hustedia indica (Waag.), var. *lineata* Reed,
Martinia buriensis Reed,
Orthoceras sp.

Middle or upper—

Streptorhynchus craticulatus Reed,
Chonetes (*Chonetina*) *wynnei* Reed,
Spiriferina (*Mansuyella?*) cf. *margaritae* Gemm.,
Spirigerella ovoidalis Waag.,
Huanghoceras warchense (Reed).
Metacoceras (*Taenionautilus*) *multicostatum* Reed,

Lower, middle or upper—

Aviculopecten asiaticus de Kon.,
Pecten flemingianus de Kon.,
Hyolithes orientalis Waag.,
Sageceras hauerianum de Kon.,

The most important and abundant element in the fauna is contributed by the brachiopods, whose sedentary habits tend towards a wide vertical rather than horizontal range. The distribution of species appears to be largely local, and the further subdivision made by Waagen has for that reason been found untenable in the field ; Noetling's zones are also of doubtful value.[1] As its name implies, the formation is characterised by the abundance in individuals and species of *Productus* and allied genera; 16 or 17 of the sub-genera of the genus *Productus* are represented.

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[1] *Neues Jahrb. f. Min. Geol. u. Pal.* XIV, table facing p. 468 (1901).

The fauna of the Productus Limestone is now universally acknowledged as wholly Permian, its three divisions corresponding roughly to the Lower, Middle and Upper divisions of that system ; not only is this the case, but it would appear to represent practically the whole of the Permian of Europe. Dr. Cowper Reed finds that there is a faunal passage from the Middle Productus Limestone to the Upper ; and these two divisions have more in common with each other than either of them has with the Lower. The Upper is, in fact, distinguishable from the Middle almost solely by the greater development of ammonoids which, however, are by no means plentiful.

Taking the divisions in order, Dr. Cowper Reed notes that the Lower Productus Limestone is characterised by the presence of *Productus* (*Dictyoclostus*) *spiralis* Waag., *Spirifer* (*Neospirifer*) *marcoui* Waag. and S. (*Pœckelmannella*) *niger* Waag., all of which are limited to this division. Restricted also thereto are *Tæniotherus*, a sub-genus of *Productus*, and, with one exception, the genus "*Aulosteges*". Very few, if any, of the brachiopods found in this division range up into the Middle Productus Limestone. *Fusulina* is abundant.

The break between the Lower and Middle divisions is intensified by the Gondwana Plant Bed at the base of the latter ; from it have been identified[1] :—

Gangamopteris cyclopteroides Feistm.,
,, *major* Feistm.,
,, *kashmirensis* Seward,
Glossopteris indica Feistm.
Annularia sp.
Branchlets, probably of Equisetaceous plants.

Carbonaceous bands, some of them with ill-preserved, unidentifiable plant remains, are said to occur at several horizons in the Warcha section, and indicate a return to the conditions which prevailed during the accumulation of part of the Conularia sequence.

The Cliff Limestones of the Middle division are described by Cowper Reed as extremely rich in species of *Productus*, *Spirifer*, *Spiriferella*, *Athyris* and *Notothyris*, many of which range up into the Upper division. The characteristic genera are ; *Lyttonia*, the peculiar *Richthofenia*, and *Kiangsiella*, while *Cancrinella* and *Haydenella*, two sub-genera of *Productus*, do not appear to range above this division.

The Upper Productus Limestone is marked by the presence of the genus, *Cryptocanthia*, but is distinguished principally by the greater development of ammonoids, as shown in the lists.

With regard to external relationships, Cowper Reed finds that the Lower Productus Limestone fauna possesses some notable affinities with that found in the Agglomeratic Slate of Kashmir, if we except the scarcity of mollusca in the latter. The resemblances are seen in the occurrence in the Lower Productus Limestone of allied species of *Tæniotherus*, of a species of *Dielasma* similar to *D. nexile* Reed, of a species of *Palæocorbula* (*P. dubia* Reed) resembling *P. difficilis* Reed, and of a gastropod *Pleurotomaria* cf. *conglobata* Wanner ?, like *Pl. brenensis* Reed. The closest resemblances are with the Lower Permian faunas of Western Australia several of the brachiopods and lamellibranchs being identical or closely allied. This division corresponds to the Lower Permain (Artinskian) of Russia.

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[1] *Rec.* LXII, 443 (1929).

With regard to the Middle and Upper divisions, many of the Salt Range forms are identical with or allied to those found in the Lopingian of China. There appears also to be a very close relationship to the Russian beds, both regions having many brachiopods in common and showing marked resemblances in their lamellibranchs and gastropods. Except in Sicily, the Trogkofel and the Carnic Alps, the Permian faunas of the rest of Europe contain very few species identical with or allied to Salt Range forms ; those that are, show affinities with the Upper rather than the Middle Productus Limestone assemblage. Middle and Upper Productus Limestone species or allied forms are known to occur in Persia and Armenia. The Middle and Upper Permian of Indo-China contains comparatively few species common to the Salt Range, but the rich and probably Upper Permian fauna of Timor, Rotti and Sumatra contains some of the brachiopods and ammonoids of the Upper Productus Limestone. The Productus Limestone has been recognised in the ' Oman peninsula' of Arabia.[1]

THE PANJAL VOLCANIC SYSTEM OF KASHMIR AND OTHER PARTS.

General distribution and relationships.—What are now the north-western end of the Himalayan chain and the northeastern parts of Hazara were the scene of extensive and prolonged volcanic activity during the latter part of the Carboniferous, the whole of the Permian and most of the Triassic periods. The eruptions took place either on an old coastal land surface subject to occasional transgressions of the sea, or on a submarine shelf. In general, this volcanic cycle is characterised by a thick series of ashes and tuffs known as the Agglomeratic Slate, followed by an usually thicker succession of basic lava flows, the Panjal Trap. Between the two or interbedded with either, bands of the so-called Infra-Trias limestone are seen in some sections, especially in the acute re-entrant of the Hazara-Himalaya syntaxis.

It was at first undecided whether the Agglomeratic Slates were of volcanic or of glacial origin, but the discovery by Wadia of undoubted tuffs with fragments of glassy matter among representatives of this group in the Pir Panjal confirms the preference shown originally by Middlemiss for a primary volcanic origin. In some cases the tuff-like character of the beds is demonstrated by well-shaped phenocrysts of orthoclase, plagioclase and quartz, scattered in a matrix which may be either a devitrified glass or black and opaque. The tuffaceous character, according to Wadia, applies not only to the often highly vitreous matrix of the dense, black, cleaved slates, but also to that of many of the coarse quartzose, sandstone-like beds of the series.[2] The suspected equivalence of the basal portion of the Agglomeratic Slate to the Talchir Boulder Bed of other areas remains yet to be proved, for the reported discovery in one locality of ice-scratched and facetted pebbles in the deposits has not been confirmed ; the subsequent re-arrangement of some of the tuff as gacial tillite, however, is a possibility which cannot be ignored.[3] In the Nagmarg area, some of the beds of the Agglomeratic Slate series enclose sub-angular pebbles, some of them as large as the first.[4]

Not only are the Agglomeratic Slates and the traps frequently found together over large parts of Kashmir, but they are often interbedded with each other at their mutual junction. In the Pir Panjal, the two series are so intermingled that it is impossible to differentiate them on the map. In view of these facts, these two groups must be looked upon as forming two phases of a single system. In spite of the danger of confusion due to previous uses of the name, there seems no more appropriate term for this system than Panjal. In a general way, Lydekker's "Panjal Trap" corresponds to the upper series of this Panjal system, and his "Panjal Conglomerate", to some extent at any rate, to the lower or Agglomeratic Slate series.[1]

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[1] G. M. Lees. *Q. J. G. S.*, Vol. LXXXIV, 594 (1928).

[2] *Rec.* LXVIII, 151 (1934).

[3] *Gen. Rep. Rec.*, LXI, 20 (1918).

[4] H. S. Bion and C. S. Middlemiss. *Pal. Ind.* New Ser. Vol. XII, 7 (1928).

In the Lidar valley area, the Agglomeratic Slates are described as passing down into the Fenestella series. Along the northeastern flank of this anticline, in a southeasterly direction, the Panjal traps overlap successively but with no appreciable discordance the Agglomeratic Slates, the Fenestella series (Middle Carboniferous), the Syringothyris Limestone (Lower Carboniferous), and lie ultimately upon the Muth Quartzite (Devonian and Upper Silurian) with only a thin conglomerate between.[2] West of the Sind valley, the unconformity below the Panjal Trap and Agglomeratic Slate is exaggerated by similar progressive overlap in this direction, both the pyroclastic and effusive members of the system transgressing the edges of successively older beds. North of the Wular Lake, a thin band of the Agglomeratic slates, some 200 feet in thickness, underlies the Panjal traps and reposes in sharp unconformable contrast upon slates with Upper Cambrian trilobites or upon beds presumed to belong to the Lower Cambrian ; this very modest thickness represents only the uppermost beds of the Agglomeratic Slate series, everything below it, the lower horizons of the series itself, the Fenestella Shales, the Syringothyris Limestone and the Muth Quartzite being absent through overlap, erosion or non-deposition. In the exposure south of Baramula and elsewhere, the volcanic rocks rest unconformably upon the Salkhala ; in the mountains near Gulmarg, the Panjal traps are seen lying upon either the Tanawals or the Dogra Slate. In short, while in the eastern parts of the Kashmir valley the tuffs of this formation can be seen to have mingled with the sediments of the Fenestella series, in the more westerly portions, around and to the north of Srinagar, they spread over a denuded surface composed variously of the Syringothyris Limestone, the Muth Quartzite, the Tanawals, the Cambrian, the Dogra slates or the Salkhala schists.

(1) THE AGGLOMERATIC SLATE.

The typical agglomeratic slate of the Panjal volcanic system is a dark grey rock, minutely speckled with white, with here and there larger patches of white and grey. On weathering, it disintegrates and crumbles rapidly, taking on a browner tint and becoming pitted all over with angular cavities left by the falling out of fragments. In general terms, it is a fine grit or graywacke, merging into slate, with an unresolvable confused matrix, in which are set quantities of small angular grains of quartz and, at wider intervals, slightly larger angular fragments of quartzose rocks and occasionally of slate and limestone.[1] At still wider intervals and dotted about at random are still larger fragments, ranging in size up to that of the fist, sometimes rounded but more generally sharply angular, composed of quartzose rocks with occasional slate and limestone and rarely of quartz-porphyry, felspar, pegmatite and tourmaline-granite. The finer-grained type is the predominant rock, and is easily recognized by the angular fragments it contains or by the cavities whence such fragments have weathered out on exposed surfaces.[2] Like all fine-grained rocks of this region it is generally imperfectly cleaved. There seems little doubt that, as originally and tentatively described by Middlemiss, the agglomeratic slate of Kashmir is " an accumulation of clastic and sedimentary material formed round ruptured portions of the earth's crust which eventually became foci for the extrusion of basic lava flows."

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[1] Included in Lydekker's "Panjal system" are some much older chloritised traps belonging to the Dogra Slates ; these are in some cases amygdaloidal, contemporaneous lavas, now converted into schists, in other cases intrusive dykes. The "Panjal Slates" are the Dogra Slates *plus* the Agglomeratic Slate. The "Panjal system" of Lydekker, in fact, comprises an immense thickness of slates and traps, now divided into (*a*) the Salkhala series and the Dogra Slates ; (*b*) a sequence of six divisions of Palæozoic sediments ranging from Cambrian to Middle Carboniferous ; and (*c*) the Panjal Volcanics, comprising the Agglomeratic Slate and the Panjal Trap.

[2] C. S. Middlemiss. *Rec.*, XL, 235 (1910).

The Agglomeratic Slate beds are not entirely unfossiliferous and to the east of Hundwara many fossil localities have been noted, the fossils being confined to the soft brown, sandy beds. These marine fossiliferous sediments associated with the slates sometimes assume a considerable size, but there is usually a large porportion of volcanic debris mingled with the clays and sands. Two principal horizons have been established by Middlemiss and Bion. The lower, or zone of *Syringothyris lydekkeri*, is found in the Marbal anticline 800 feet above the base of the series, and also near Kolahoi ; it has yielded the following :—

Bryozoa—

Protoretepora cf. *ampla* Lonsd.
Fenestella aff. *internata* Lonsd.

Brachiopoda—

Syringothyris lydekkeri (Dien.),
Camarophoria dowhatensis Dien.,
Spirifer (*Paeckelmannella*) *middlemissi* Dien.
,, ,, *varuna* Dien.
,, ,, (*Spiriferella*) *personata* Reed (Bion's "*Sp.* aff. *niger* Waag".)
Derbyia cf. *regularis* Waag.,
Productus cf. *scabriculus* Mart (resembles a variety of Reed's *Pr.* (*B.*) *kashmiricus*),

a fauna almost identical with that of the Fenestella series, and considered to belong to the Moscovian or Middle Carboniferous. The ocurrence of what is in reality a band of the Fenestella beds amongst the basal tuffs of the Agglomeratic Slate fixes the date at which the latter commenced to spread over this region.

The upper horizon or zone of *Syringothyris nagmargensis* Mid. and Bion is typically displayed in the Nagmarg area and occurs also in the Marbal anticline about 100 feet below the base of the Panjal Trap ; though somewhat later than the Salt Range Conularia Beds, it may be assigned to the Uralian and includes the following forms :—

Bryozoa—

Protoretepora ampla Lonsd.
Fenestella aff. *internata* Lonsd.
Stenopora sp.

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[1] *Pal. Ind.*, New Ser. Vol. XII, 4 (1928).

[2] *Rec.*, XL, 233 (1910).

Brachiopoda—

Syringothyris nagmargensis Mid. and Bion,
Spirifer (*Neospirifer*) *nitiensis* Dien., and two varieties,
,, ,, *fasciger* Keys. (perhaps equivalent to *S.* (*N.*) *musakheylensis* Dav.),
,, ,, *kimsari* Bion.
,, (*Spiriferella?*) *stokesi* (Koenig), var. *australis* Mid. and Bion, and two other varieties,
Spiriferina cf. *laminosa* McCoy, var. *sterlitamakensis* Tschern. (possibly identical with the Bren Spur form, *S. duodecimcostata* McCoy).
Productus (*Buxtonia*) *scabriculus* Mart. (perhaps equivalent to Cowper Reed's *P.* (*B.*), *kashmiricus*),
,, (*Linoproductus*) *lineatus* Waag. (perhaps referable to *Productus* (*Taeniotherus*) *brenensis* Reed[1]
,, *undatus* Defr.,
Dielasma sp.,
Streptorhynchus bioni (?) Reed,
Chonetes sp.

Lamellibranchiata—

Lima sp.,
Pinna sp.,
Deltopecten cf. *illawarensis* Mor. (probably identical with Cowper Reed's *Aviculopecten* cf. *mitchelli*),

From the Agglomeratic Slate of the Bren spur near Srinagar, a fauna differing from that of some localities in the same series, is probably more or less equivalent to the Nagmarg fauna or zone of *Syringothyris nagmargensis*. Fossils have been collected from six or seven different levels and determined by Dr. Cowper Reed; they may be grouped under three zones which, however, show but slight or inconstant faunistic distinctions.[2]

Zone(c)[3]

Bryozoa—

Fenestella ? cf. *fossula*, Lonsd. (*Fenestrellina*).
Stenopora cf. *crinita* Lonsd.

Crinoidea—

Crinoid stem joints.

Brachiopoda—

Productus (*Cancrinella*) cf. *koninckianus* de Vern.,
,, (*Taeniotherus*) *permixtus* Reed (resembles *P. subquadratus* of the Australian "Permo-Carboniferous"),
,, ,, *brenensis* Reed (perhaps merely a variety of the preceding),
,, (*Buxtonia*) *kashmiricus* Reed, and a variety.
Strophalosia cf. *clarkei* Ether.
,, cf. *gerardi* King,
Streptorhynchus cf. *hallianus* Derby ? (perhaps equivalent to *Derbyia buriensis* Reed, from the Lower Productus Limestone).
Rhynchonella cf. *jukesi* McCoy.,
Spirifer (*Fusella*) cf. *avicula* Sow.
Spirifer (*Neospirifer*) *fasciger* Keys, var. *paucicostulata* Reed (a Chitral form),
,, ,, *hardmani* Foord. var,
,, (*Brachythyris*) *darwini* (Morr.) Salt Range (a species found also in New South Wales).
,, (*Neospirifer*) *kimsari* Bion,
Spiriferella personata Reed,
Syringothyris nagmargensis (Bion),
Dielasma cf. *lidarense* Dien. (perhaps identical with *D. dadanense* Reed from the Salt Range Upper Carboniferous *Eurydesma* beds).
Orthis (*Rhipidomella*) sp. (cf. *O.* (*Rh.*) *australis* McCoy).
Leptaena analoga (Phillips) (wide distribution).

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[1] *Pal. Ind.*, New. Ser., Vol XX, *Mem.* 1, p. 15 (1932).

[2] *Pal. Ind.*, New Ser. Vol. XX, *Mem.* 1, pp. 6-10 (1932).

[3] Mr. R. D. Thompson's Horizons E, F and G: Middlemiss' "Locality 2" (1929) and his Horizons 1, 3 and 4 of 1930.

Lamellibranchiata—
Sanguinolites kashmiricus Reed,
Allorisma sp.
Mœonia gracilis Dana, var.,
,, (?) *arbitrata* Reed,
Conocardium sp.,
Parallelodon cf. *interrupta* (de Kon.),
Aviculopecten aff. *subquinquelineatus* McCoy,
Limatulina aff. *krotowi* (Stuck.) (Species found in the Upper Carboniferous of Russia.),
Astartila elusa Reed,
,, *transversa* Dana,
Pleurophorus cf. *tropidophorus* Meek (Species found in the Upper coal measures of Kansas).,
Procrassatella brenensis Reed, (peculiar species),
,, *intermedia* Reed, (peculiar species),
Palaeocorbula difficilis Reed.

Gastropoda—
Pleurotomaria aff. *conglobata* Wanner ·(Species found in the Permian of Timor),
,, cf. *euglyphea* Girty (a Pennsylvanian form),
Modiola sp.,
Bucania cf. *warthi* Waag. (a Salt Range form),
Tropidocyclus sp.,
Euphemus carbonarius (Cox) well-known in the Upper Carboniferous of N. America, found also in Peru , Chitral and probably the Salt Range).
Warthia micromphala (Morris) (found also in New South Wales),
Zone(b)[1]

Brachiopoda—
Streptorhynchus bioni Reed,
Syringothyris nagmargensis (Bion),
Spirifer (*Spiriferella ?*) cf. *stokesi* (Koenig) var. *A.* (Bion),
,, (*Neospirifer*) *hardmani* Foord, var.
,, (*Neospirifer*) *fasciger* Keyserl., var. *australis* Foord,
Spiriferina duodecimcostata (McCoy) (an Australian species)
Martiniopsis sp.
Reticularia kashmirica Reed (Perhaps identical with New South Wales form)

Lamellibranchiata—
Sanguinolites kashmiricus Reed ; probably identical with a shell from the Conularia stage of the Salt Range figured and described by Waagen as *Sanguinolites* cf. *tenisoni* de Kon. ; Cowper Reed doubts the alliance of the latter with the true *S. tenisoni* of the New South Wales "Permo-Carboniferous".
Leda (*Nuculana*) *thompsoni* Reed (suspected of being identical with *N. basedowi* Ether. from South Australia, or with *Tellinomya etheridgei* Johnst, from Tasmania),
Parallelodon brenensis Reed,
Aviculopecten cunctatus Reed,
Eurydesma cordatum Morris, var. *mytiloides* Reed,
,, ,, ,, ,, *compressa* Reed,
,, ,, ,, ,, *subquadrata* Reed,
,, cf. *globosum* Dana,
Procrassatella brenensis Reed,
,, *intermedia* Reed,
Oriocrassatella lapidaria Reed (genus purely Australian and Indian),
Astartila ovalis (McCoy)
,, cf. *corpulenta* (Dana) (including the doubtful *Pachydomus sacculus* McCoy),
Mytilomorpha translata Reed.

Gastropoda—
Pleurotomaria brenensis Reed,
,, cf. *nuda* Dana (a Salt Range form),
Bucania cf. *warthi* Waag. (a Salt Range form),
Zone (a)[2]

Bryozoa—
Protoretepora ampla Lonsd.
Stenopora cf. *gracilis* (Dana),
Fenestella (*Fenestrellina*) cf. *fossula* Lonsd.
,, cf. *internata* Lonsd.

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[1] R. D. Thompson's Horizons B, C and D ; Middlemiss' "Locality 1" (1929).

[2] Thompson's A_1 and A_2 ; Middlemiss' Locality below No. 1 (1929).

Brachiopoda—

Spirifer (*Brachythyris*) *darwini* (Morris).

Lamellibranchiata—

Eurydesma cordatum Morris, var. *mytiloides* Reed,
Sanguinolites (?) cf. *carinatus* (Morris) (probably identical with a form described as *Pachydomus* (*Maeonia*) *carinatus* Morris from Australia),
Aviculopecten cf. *mitchelli* Ether & Dun. (species found in Australia).

Plantae—Fragments of Wood—

The differences between this fauna and that of Nagmarg are exaggerated by the small number of brachiopods and the prominence of the mollusca in the former, and may be due as much to accident in collecting or a slightly different environment resulting in a different biological facies, as to any small difference in stratigraphical horizon. This fauna shows a close resemblance to that of the Conularia beds of the Salt Range, the most noticeable difference between the two being the apparent absence of the genus *Conularia* in the Kashmir beds. Dr. Cowper Reed is inclined to assign the Agglomeratic Slate faunas of Nagmarg and the Bren spur to the Upper Carboniferous, but at the same time remarks that they have some noticeable but limited relations to the Lower Productus Limestone of the Salt Range. It is probably near the truth to say that the faunas so far discovered in the Agglomeratic Slate range from Upper Carboniferous to Lower Permian, and that the mass of the Agglomeratic Slate belongs to a period straddling the Middle Carboniferous, Upper Carboniferous and Lower Permian.

(II) THE PANJAL TRAP.

The Panjal Trap forms a series of altered lava flows, consisting for the most part of basalts or of what have been called basic pyroxene andesites,[1] of mean specific gravity 2·85. Compact and amygdaloidal varieties are equally common and some are porphyritic.

Lydekker notes the not infrequent presence of large, isolated, pear-shaped amygdules of chalcedony reaching 2-3 inches in length, and the same authority records a finely porphyritic variety of the trap from the vicinity of Srinagar, epidotised and partly metamorphosed.[2] The traps vary somewhat in texture but the coarser varieties may be intrusive sills. Externally the rock has a fresh aspect, but under the microscope extensive changes are visible and are usually sufficient to disguise its original composition. The primary constituents are plagioclase and augite, lying in a fine-grained semi-crystalline, seldom glassy groundmass, with magnetite and ilmenite as the important accessories. The lath-shaped plagioclase felspars have suffered widespread alteration to epidote, zoisite and calcite; the augite, which originally occurred in rounded irregular grains, or rarely in plates, has been almost entirely replaced by epidote, or sometimes by chlorite. Olivine is absent. Veins, threads and vesicles of epidote are everywhere apparent. If any zeolitic infilings of the amygdules ever existed, they have been replaced by chalcedony, jasper, chlorite and epidote. Glomeroporphyritic structures in the form of stellate aggregations of felspar crystals (the "Suleimanite" of Verchere) have been recorded in the Nagmarg, Shamsh Abari and other areas. There is no sign of any appreciable magmatic differentiation in the traps, and they appear to have possessed the high degree of liquidity of basic flows, their composition showing a remarkable uniformity. Individual flows are often markedly lenticular, but in other places may be found a continuous succession of thin flows extending for miles. Unusually basic and acid types, however, have been noted in the Baramula district by Dr. Coulson ; the former as epidotised, serpentinised rocks with a silica percentage as low as 43·3 and the latter in the form of devitrified and otherwise altered toscanites, accompanied by acid tuffs.[1]

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[1] D. N. Wadia. *Mem.* LI, 239 (1928).

[2] *Mem.* XXII, 218 (1883).

Inter-trappean sedimentary beds occasionally interrupt the monotony of the flows, and ashy layers are in some places, as for instance in the Pir Panjal, frequent at the top of the series and locally attain considerable thickness. These ashy layers are well laminated, bright-coloured, variegated and mottled, the usual colours being purple, buff and green ; they are often veined by steatite and, like the top beds of the trap itself, are sometimes silicified. In the Tosh Maidan area of the Pir Panjal the traps, which, incidentally, are faulted up against the Upper Trias by a cross fault, include near their upper limits some 300—400 feet of purple conglomerates and grits interbedded to some extent with the traps.[2]

The interbedded sedimentaries consist principally of unfossiliferous Infra-Trias limestone or fossiliferous Triassic limestone, and were at first suspected of being the cores and tips of sharply folded synclines involving the traps and the limestone. In the Panjal range and the Kagan valley of Hazara, however, the interbedded limestones in the body of the trap, according to Wadia, show intercalary junctions at both the top and bottom. In the Panjal range of the Uri district, there is, in more or less constant association with the Panjal volcanic system a limestone attaining a maximum thickness of over 1,000 feet but showing rapid constrictions and swellings ; the rock is not only interbedded with thin lava flows or with altered ash beds, but is itself often charged with ashy matter.[3] A few comminuted fossil shells in this limestone suggest a Triassic age. In the Kagan area, 50 to 200 feet of a white, compact, well-bedded, unfossiliferous limestone of Infra-Trias aspect are seen to be sandwiched for many miles between the Agglomeratic Slate and the Panjal Trap, but often transgressing one or the other boundary. At Ambersilwara, (Imselwara, Imbersilwar), west of the Wular Lake a thick lenticular patch of what is apparently Triassic limestone, crowded with crinoid stems, and from 200 to 300 feet thick in the middle, is clearly underlain, and overlain by a great thickness of traps along a gentle plane of dip ; the upper junction is not clearly exposed but from the underlying traps there is, according to Wadia, a perfectly gradual passage into the limestone which, at its base, is full of ashy material. A similar intercalation of much the same maximum thickness is seen in the Erin valley, to the northeast of the Wular Lake ; in this case the trap above the limestone, which is Triassic in type is some 8,000 feet thick, and towards its top shows a transgressional passage into sandy shales possibly referable to the Anisian or Muschelkalk, and thence to a thick succeeding bed of massive Upper Trias limestone, containing a little above its base a lenticular sill of the same trap.

Between Bandipur and Tragbal, the thickness of the Panjal Trap has been estimated at between 5,000 and 7,000 feet or even more.[4] In the vicinity of

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[1] *Gen. Rep. Rec.* 73, 18 (1938).

[2] C. S. Middlemiss. *Rec.* XLI, 131 (1911).

[3] *Rec.* LXVIII, 164 (1934).

[4] *Rec.* LXVIII, 159 (1934).

Gulmarg it exceeds 6,000 feet,[1] while in the Erin valley it must be appreciably greater than 8,000 feet, according to Bion.[2]

The Panjal Trap is described as building fine walls and precipices of rock which fill the ravines at their feet with enormous blocks and boulders. Its topography is characterised by bare, bold, sharply rugged outcrops, with abundant screes and gigantic landslips. On the shores of the Wular Lake, the weathering of the trap recalls the lateritization of the basalt of the Deccan plateau in its change to a deep, brick-red clay and ferruginous soil-cap. Spheroidal weathering is sometimes seen.

(III) STRATIGRAPHICAL LIMITS OF THE AGGLOMERATIC SLATE AND THE PANJAL TRAP.

Not only is the thickness of the Agglomeratic Slate very variable, but so is the lowest stratigraphical horizon at which it appears in different sections, according to Mr. Middlemiss. In Marbal, for instance, this lower limit coincides with the lower part of the Middle Carboniferous or Moscovian ; in the Lidar valley it corresponds to the upper part of this stage ; in the Nagmarg area it corresponds to the top of the Uralian or possibly the bottom of the Artinskian, though lower beds may here be hidden by unconformable overlap. At the top of the Nagmarg outcrop of Agglomeratic Slate is a thin layer of shales from which were collected specimens of *Gangamopteris*, *Glossopteris* and *Psygmophyllum*—beds referable probably to the Uralian and equivalent to similar beds on the Risin spur in the Guryul ravine. The more intense outbursts of volcanic activity date generally from the end of the Uralian.

Middlemiss remarks that "if the beginnings of vulcanicity in this region may be presumed to have varied so widely at different places during the Carboniferous period, the end of it, as marked by the uppermost layers of the Panjal Trap, shows an even greater variability. For instance, in some few places (*e.g.* Khunmu) the top bed of trap forms a floor for the Gondwana *Gangamopteris* beds, though more generally it has shifted a little higher to the base of the marine Zewan series (Permian), as found over most of the valley part of Kashmir."[3]

Along the northern flank of the Basmai anticline, Bion found a distinct invasion of the Zewan (Lower and Middle Permian) by the Trap, the upper surface of the latter shifting upwards to higher levels within the Zewan beds and cutting out the two well-marked and elsewhere constant fossiliferous horizons of "*Spirifer rajah*" and *Protoretepora ampla*, the Zewan at the same time being reduced in thickness from 250 feet near Sonamarg to 50 feet farther northwest. Actual proof of this invasion is recorded in a bed of the trap, 200 feet thick and amygdaloidal in character interbedded with the Zewan strata in the form of a wedge emanating from the main mass of the trap. According to Middlemiss, the upper limits of the Panjal Trap show a still more marked encroachment to the northeast of the Wular lake where it appears successively in contact with the Lower, Middle and Upper Trias, large patches of these rocks lying entirely enclosed within the outcrop of the trap. Two of these outliers, one at Ambersilwara west of the Wular lake, and the other in the Erin valley to the east of the lake, have already been mentioned. Vulcanicity in the Shamsh Abari and Gulmarg areas did not end until well into the Upper Triassic period.[4]

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[1] *Rec.*, XLI, 131 (1911).
[2] D. N. Wadia. *Rec.*, LXVIII, 162 (1934).
[3] *Pal. Ind.* New Ser. Vol. XII, 13 (1928).
[4] D. N. Wadia. *Rec.*, LXVIII, 161 (1934).

Bion's work has shown that between the Lidar valley and the Wular Lake the Panjal Trap varies in horizon from pre-Permian to the base of the Upper Trias. The lavas, some of them amygdaloidal, accompanied by beds of ash and pumiceous material, dovetail with sediments of varying age, although obviously belonging to one connected and continuous phase of volcanic activity.

The significance of this behaviour of the tuffs and traps cannot be better expressed than in the words of Middlemiss who remarks: "All this would seem to point to an extended phase of vulcanicity, cutting obliquely through the time-scale as represented by standard fossil zones and by well-defined sedimentary series; so that, having begun at one locality in Middle Carboniferous times, this extended phase of vulcanicity eventually ended elsewhere in the same neighbourhood at the close of the Middle Trias period (at the early part of the Upper Trias). Estimated by any available standards for those ancient times, this must have covered a very long period, during which the agglomerate and the erupted basic lavas had this peculiarity, that the type of volcanic rock did not change and did not alternate with anything else, except very locally. We appear to be required to believe that whilst changes in the marine faunas were so marked during those epochs that, for instance, whole types of Spirifers appeared, spread themselves over the earth and one by one disappeared, and that similar whole types of Ammonoidea went through the same elaborate processes of world-wide development and extinction--whilst all this was taking place (slowly, we can only think), the Panjal Trap kept up a persistent and uniform emission of the same unchanged magma, the relics of which are now found as one coherent block of bedded trap."[1] This *échelonnement* of Panjal vulcanicity through the various geological epochs has been graphically illustrated by Wadia[2] (See fig. 16).

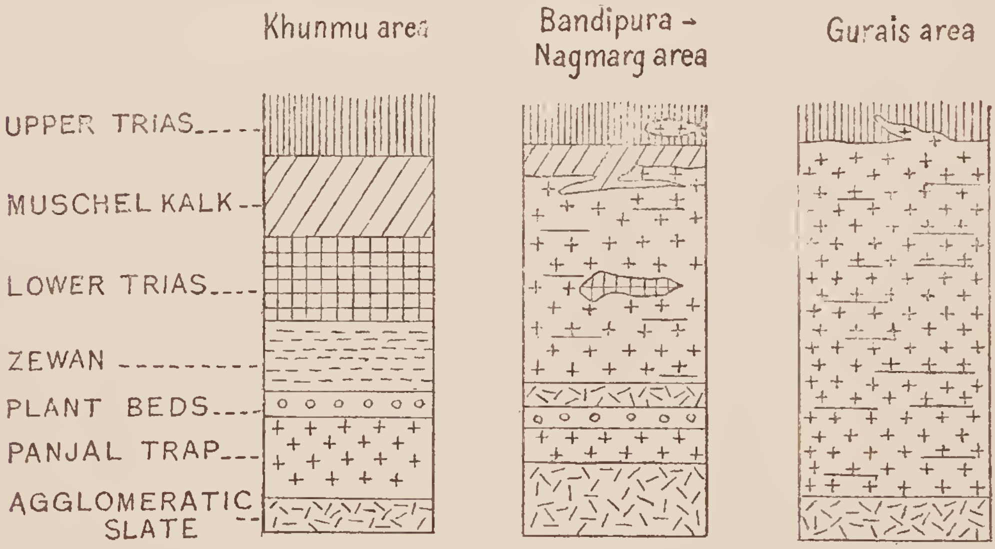

Fig. 16.

It is difficult to picture such a continuous volcanic effort spread over this long interval of time, nor does it seem possible to take refuge in a refusal to believe that the Trap was poured out over the surface either of the land or of the sea bottom, and was not intruded as sills during some later period such as that of the Rajmahal or the Deccan Trap, for all those who have examined the Panjal Trap are agreed that the great bulk of it is effusive. This being so, the Panjal Volcanic system was not only a volcanic facies of the marine Permian, and Lower and Middle Trias of the more eastern areas (Vihi, Lidar, Banihal, etc.), but accompanied the deposition of Middle and Upper Carboniferous limestones.

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[1] *Pal. Ind.* New Ser., Vol. XII, 13 (1928).

[2] *Rec.* LXVIII, fig. 3, p. 158 (1934).

(IV) PANJAL INTRUSIVES.

In the Lolab and Hundwara districts of Kashmir and elsewhere, a genetic connection is to be noted between the amygdaloidal lavas of the Panjal Trap and the numerous dykes of dolerite injected into the Silurian and older Palæozoic rocks of the region. In these hypabyssal roots of the eruptions, some of them of considerable size, uralitisation has been complete and universal.

Through the axial zone of the Panjal range, laccolitic bosses of coarse gabbro and norite have intruded the Agglomeratic Slates; one of them, just east of the Panjal Pass is two-and-a-half miles in width. Closely associated with these bosses is a group of sills and large sheets of dolerite, much of which has been altered to epidiorite; examples of these are well exposed in the gigantic precipices on the southwest side of the crest of the range. Finally, there is an extensive system of smaller dykes and sills of lamprophyre traversing the Agglomeratic Slates as well as the older Dogra Slates, chiefly along their cleavage planes; the smallest of these have been so altered as to be scarcely distinguishable from the country-rock invaded. Most of these intrusive rocks, including even the coarser types, have been extensively uralitised and chloritised. About two miles west of Hurapor (Hirpur), the gabbroid sills in the Agglomeratic Slates can be traced into actual connection with the lava of the Panjal Trap.[1]

Intrusive into the Hazara Slates, the Tanawal quartzites and the Infra-Trias of the Hazara district, there are a few basic trap dykes, usually doleritic in character but grading in metamorphic stages to a hornblende schist; the latter type forms the edges of a dyke cutting through the gneissose granite of the Indus river. In texture there is variation from a moderately coarse dolerite to a fine aphanitic rock, but the rocks are all dyke rocks and there are no corresponding flows of Panjal trap; if any of the latter ever existed in this region, it has been completely removed by denudation. The basic dykes of Hazara cover no large surface and are described as roughly parallel to the foliation of the intruded rock.[2]

(V) SOME INDIVIDUAL OUTCROPS OF THE PANJAL VOLCANICS.

Lidar valley.—Enormous thicknesses of the Agglomeratic Slate are found in the Lidar valley and, since they constitute part of a normal anticlinal sequence, forming one of the crescentic outcrops which characterise the pitching anticline northeast of Islamabad, any reduplication is unlikely. Except for a few crinoid stems near Trahal, no fossils have been found in this series in the Lidar valley. The beds are described as passing down into the Fenestella Shales and as being interbedded with the succeeding Panjal traps; the latter in turn underlie Lower Gondwana beds and these are followed by the Zewan beds.

The Panjal Traps of the Lidar area are described as distinctly bedded and very massive, with frequent amygdaloidal bands. As in the case of the Agglomeratie Slate, many thousands of feet appear to be exposed in normal sequence. None of the trap in this area appears to be porphyritic. Dykes and laccolithic masses of probably the same magma are seen cutting through the Agglomeratic Slate on the one side and the Fenestella Shales on the other; one dyke is seen cutting the Lower Trias.[3]

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[1] D. N. Wadia. *Mem.*, LI, 221-223 (1928).

[2] C. S. Middlemiss. *Mem.*, XXVI, 75 (1896).

[3] *Rec.*, XL, 236 (1910).

Marbal valley area.—The Marbal valley anticline lies southeast of Islamabad, pitching gently northwest, *en echelon* with the Lidar valley anticline, the country between being complex in structure. The Muth Quartzite is absent, though present in the neighbouring anticline to the northeast. Here again, the core of the fold is made up of the Silurian slates, on which rest 500 feet of the Syringothyris Limestone. The latter passes up regularly into an equal thickness of interbedded black shales and quartzites belonging to the Fenestella series. Next in regular sequence, and in very great thickness, comes the Agglomeratic Slate, which in a few places contains unusually large blocks and boulders reaching the size of a man's head.

In the vicinity of the Lidar and Marbal valleys, the type rock of the Agglomeratic Slate has been found to diminish rapidly in varying degrees until reduced to a few thin layers intercalated with sandstones and ordinary black slates ; it is in such areas that fossils have been found in somewhat greater profusion.

Banihal area.—South of Islamabad, just below the Banihal Pass in the Pir-Panjal, is a similar but wider anticline pitching towards the northwest. The Agglomeratic Slate, however, is here relatively thin while the Fenestella Shales are correspondingly thick ; the two stages in fact seem to be compensatory one towards the other, a view supported by the similarity of the fauna of the lower part of the Marbal Agglomeratic Slate to that of the Fenestella Shales of the Lidar valley.

Basmai-Kolahoi.—Northeast of Srinagar, the Agglomeratic Slate and Panjal Trap are exposed in an anticline pitching in a southeasterly direction towards the peak of Kolahoi (17,830 feet). According to Middlemiss and Bion, this anticline is parallel to the Lidar anticline, and by pitching in an opposite direction, is complementary thereto. The intervening area, covered by Panjal Trap, is bent into two synclinal troughs or basins carrying Permian and Triassic strata. The Agglomeratic Slate is overlain everywhere by the Panjal Trap. Below, the Fenestella Shales appear to be absent, and for the most part the base of the Agglomeratic Slate, in the form of a pebbly conglomerate, rests unconformably upon the Syringothyris Limestone. According to Middlemiss and Bion, the Panjal traps overlap not only the Agglomeratic Slate, but the whole of the rest of Carboniferous system as well as the Muth Quartzite and, whether by overlap or faulting, lie directly upon the Silurian Slates for many miles around the periphery of the latter outcrop.[1]

Agglomerate is here subordinately developed. The lower part of the formation is characterized by conglomerates and agglomerates, the former being fossiliferous throughout about 2,000 feet of the sequence ; the upper part is composed of black slate without pebbles. Bands of trap are frequent, especially in the upper part ; some at least are flows with the upper surfaces amygdaloidal, some may be sills, and the thin stringers are probably dykes. The topmost layer of the Agglomeratic series, immediately below the Panjal Trap, is a black slate in which lie irregularly blocks of trap of all sizes. These are thought to be the result of lava flows and bombs entering a shallow sea, and are well seen north of the snout of the Kolahoi glacier where the trap in the slate is not unlike a pillow lava.[2] The Sind river gorge is said to cut through at least 6,000 feet of Panjal trap, which builds the usual precipitous crags.[3]

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[1] De Terra infers that the contact between the Panjal Trap and the younger Palæozoic rocks is largely of a tectonic nature—presumably a fault or thrust—and not due solely to unconformity with overlap. *Mem. Connect. Acad.*, VIII, **Art. II, 26** (1935).

[2] *Pal. Ind.* New Ser. VOL. **XII**, 10 (1928).

[3] *Rec.*, **XLI**, 143 (1911).

Nagmarg area.—Reference has already been made to the Nagmarg area, north of the Wular Lake. A great part of the Panjal Volcanic beds must be buried beneath the alluvium of the Jhelum river and the Wular Lake. From Lydekker's description, the Nagmarg horizons of the Agglomeratic Slate probably occur under the Panjal traps near Kanjalwan on the Kishenganga river to the northeast.

Zoji La.—The Panjal Trap is present near the Zoji La in a much crushed fold.

Pir Panjal.—The Agglomeratic Slate and Panjal Trap are exposed along the central axis of the Panjal, a range crossed on the journey up from Rawalpindi through the Baramula gorge to Srinagar. This range, rising to a general altitude of 15,000 feet or more, is continued to the northwest across the Jhelum river by the Kajnag range, and is obscurely connected towards the southeast across the Chenab river with the Dhauladhar range ; it is heavily wooded along its northeastern face up to the 12,000 feet level. The central line of culminating peaks forming the watershed, which wanders somewhat irregularly, consist either of Panjal Trap in both amygdaloidal and compact varieties, or of Agglomeratic Slate, or in one or two places of metamorphosed Tanawal beds. Much of the jagged crest with its pinnacles and peaks, including Tatakuti (15,524 feet), is made up of the Agglomeratic Slates permeated by intrusive sills of dolerite;[1] since they have shared in the isoclinal folding of the range, no estimate of their thickness has been found possible but in places the slates and sills are described by Wadia as forming clean bare cliffs 6,000 feet in height. Along the outer margin of the range, a constricted belt of this series forms an interrupted inlier more or less enclosed in the Eocene or Palæocene limestone outcrop. This inlier is in places flanked by small patches of Permian and Lower Trias, and towards the south is in contact on its northeastern side with the Dogra Slates (Purana) instead of the Tertiary limestone ; it forms part of a recumbent anticline which is more or less complete in both its limbs from the neighbourhood of Uri for sixty miles in a southeasterly direction along the foot of the range.

The Agglomeratic Slate which attains a thickness of thousands of feet in the Pir Panjal, is described as conspicuously interbedded with the Panjal Traps, the trap flows swelling out or disappearing within short distances among the Slates. Where flows are absent, the Agglomeratic Slate is thicker, and the two types are to some extent compensatory. In fact, the superiority in age of the Agglomeratic Slate over the trap, which is so clear in the Lidar valley area, is no longer maintained in the Pir Panjal, where the two form, as it were, one outcrop. Where the lower contact is with the Tanawal series, as it is for about thirty miles, the base is frequently a conglomerate with a matrix much resembling the Agglomeratic Slate itself. In the lower horizons also have been noted pyritous casts of the zoaria of *Fenestella* and *Protoretepora*. Further north in this main exposure, it is the traps which are in contact with the Tanawals. Sedimentary interruptions, in the form of conglomerates, quartzites and sandstones are recorded in the Pir Panjal exposure of the Agglomeratic Slate formation.

The Panjal Trap of this area forms a bedded mass, penetrated here and there by white quartz veins. Near Gulmarg it exceeds 6,000 feet, but within the confine of Punch the thickness is not more than 3,000 feet.[2] A fine section is seen in the Mandi gorge, east of the town of Punch, where about 2,000 feet of steeply-dipping bedded flows are laid bare in precipices.

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[1] D. N. Wadia. *Mem.*, LI, 237 (1928).

[2] C. S. Middlemiss. *Rec.*, XLI, 131 (1911).

The trap forms the summit zone from the vicinity of Gulmarg southwards for some miles, including the peak of Shin Mahinyu (15,113 feet) and others, but further in this direction it disappears from the crestal region, its place being taken by the Agglomeratic Slate. Where it accompanies the Agglomeratic Slate to form an inlier in the Eocene outcrop, it rises steeply out of the Eocene limestones in a line of rugged crags ; here it formed the old floor on which the limestones were deposited.

Traversing the ill-defined boundary line between the Tanawal outcrop and the Dogra Slates near Buniyar, southwest of Baramula, is a plug of gabbro surrounded by doleritic masses, the central plutonic rock changing gradually through moderately coarse dolerite to fine-grained amygdaloidal lava flows exhibiting a close petrographic resemblance to the Panjal Trap.[1]

Shamsh Abari area.—In the Shamsh Abari syncline, the outcrop of the Agglomeratic Slate is almost completely hidden in the western half by the overlap of the Panjal Trap ; in the eastern half the thickness is only 100-200 feet.

Gurais area.—In the Gurais valley, on the southern flank of the Great Himalaya, the top flows and ash beds attributed to the Panjal Trap series over a considerable stretch of country, are said to pass gradually up into the massive grey limestones of the Upper Trias with no indication of unconformity or mechanical contact ; the Triassic limestones are described as crowded with pyroclastic debris.[2] Traced southeastwards, successive belts of Middle Trias, Lower Trias and Zewan beds emerge in normal order of succession between the Traps and Upper Trias ; in Gurais and also in Tilel these three series—Middle Trias, Lower Trias and Zewan —have, according to Wadia, every appearance of being represented by a continuation of the Panjal volcanic period. As we have seen, in the Shamsh Abari area, and to the south of Baramula, the Upper Trias lies on the highest traps.

Devigarh.—Interbedded with the dolomitic limestone of Infra-Trias aspect at Sumlar, at the foot of the southern fault-cliff of Devigarh in the outer Himalaya of Jammu, are 150 feet of unaltered, black, slaty tuff, composed of glass with tiny crystals of felspar, quartz and biotite, and indistinguishable from typical Agglomeratic Slate.

Himalaya-Hazara Syntaxis.—The Agglomeratic Salte and the Panjal Trap with included bands of Infra-Triassic limestone, have been traced all round the syntaxial angle between the mountains of Hazara and the northwestern extremity of the Himalaya, and constitute the floor on which the Trias and Eocene were deposited. The Panjal Volcanics here occupy the core of a great recumbent, disrupted and sheared anticline in which are also involved the Infra-Trias, Trias and Eocene. This anticline extends with almost unbroken continuity throughout the re-entrant, though its northern limb is largely over-ridden by sheets of the Salkhala schists and Dogra slates thrust from the north. In the most northerly section of the syntaxis, there are about 6,000 feet of the traps and over 3,000 feet of Agglomeratic Slate.[3]

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[1] *Gen. Rep. Rec.*, LXV, 125 (1931).

[2] The Panjal age of these volcanic beds needs confirmation. Very similar beds, a little further east and northeast, originally mapped as Panjal, are now known to belong to the much younger Dras Volcanics of Cretaceous-Eocene age. *Rec.*, LXVIII, 155 (1934) ; *Ibid.*, LXIX, 62 (1935); *Ibid.*, LXXII, 156 (1937).

[3] *Rec.*, LXV, 210 (1931).

The most general sequence, given by Wadia, is as follows :—

(Trias)

Epidotised, basic, amygdaloidal lava sheets, with thin beds of chloritised and epidotised ash, and intercalated bands and lenses of Infra-Triassic limestone	2,000—5,000 feet
A thicker band of white-weathering, thin-bedded, semi-crystalline, dolomitic limestone (Infra-Trias)	50—200 feet
Agglomeratic Slate ; soft, dark, pyritous, imperfectly cleaved, glassy tuffs and quartz-agglomerates, interbedded with grits, tuffaceous sandstones and conglomerates. The beds include some rare, badly-preserved *Fenestella*-like fossil structures	3,000 feet

(*Base not seen*)

Hazara.—The Agglomeratic Slate extends westwards into the Bhagarmang range of northeastern Hazara, and northwards to the mountains of Kagan. Some basic trap dykes found seaming the Tanawals, Infra-Trias and Attock Slates, but none of the younger rocks, in Hazara, probably belong to the Panjal traps.[1] These dykes, varying from a moderately coarse dolerite to a fine aphanitic rock, are seen intruding both the schists and the gneissose granite ; Middlemiss was of opinion that they cut through the Infra-Trias beds as well. There are no lava flows such as are seen north of the Dudatoli area ; all occurrences are in the form of dykes, though plutonic representatives of the latter are inferred to be present higher up the Indus. Along the edges of some of the foliated varieties of dyke cutting the gneissose granite, the rock becomes a hornblende schist. These narrow bands or dykes are as a rule roughly parallel to the foliation of the intruded rocks but sometimes cut across both the schists and the gneissose granite intrusions. Ophitic augite is sometimes seen in the rock, and there is a fairly complete gradation from a plagioclase-augite rock to a true hornblende schist. A columnar variety of trap has been recorded. Some of these rocks are serpentinized and some are characterized by the presence of epidote. Foliated epidiorites are amongst the varieties.

Chitral and Gilgit.—Around the village of Mirkani in the south of Chitral an agglomeratic slate, composed of fragments including rolled boulders and large angular blocks of volcanic rocks, passes upward through a slaty conglomerate into a grit, and probably represents the Agglomeratic Slate series of the Panjal volcanics. In places these beds are greatly crushed and cleaved. Above Badurgal, this agglomeratic slate is associated with trap, but the greater part of the formation is made up either of breccia or of conglomerate.[2]

In the Yasin political district of the Gilgit Agency, a trap of Panjal type was traced by Hayden from Yasin village southwards to the junction of the Yasin and Ghazar (Ghizar) rivers, interrupted midway by intrusive granite. This trap is overlain unconformably by Cretaceous rocks. In one section, the trap is in contact with beds of crystalline limestone penetrated by veins of the volcanic rock ; the limestone gives place to a conglomerate which might represent the Agglomeratic Slate. These rocks were not observed in the Baroghil-Ailak area, forty or fifty miles farther north.

Kanawar.—The trap seen intruding the Lipak and Po Series in the Kanawar area of Bashahr may belong either to the Panjal suite or to the much younger Dras Volcanics.

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[1] C. S. Middlemiss. *Mem.*, XXVI, 75 (1896).
[2] S. W. Visser. *Rec.*, XLV, 278 (1915).

Traps of Mandi.—Under this heading may be mentioned the traps of Mandi State, which have been described by Col. C. A. McMahon,[1] and have been found by Dr. W. D. West to resemble macroscopically and microscopically the Panjal Trap. These rocks build up the ridge to the east of Drang and are seen in the bed of the Suketi at Mandi town in the same line of strike.

The traps of Mandi are composed of altered basalts, mostly of a greenish grey colour, and include both compact and amygdaloidal varities; the specific gravity of the compact types varies from 2·83 to 2·93. The groundmass is cryptocrystalline in some sections but for the most part consists of what is probably a glass devitrified to an opaque, amorphous mass of viridite and leucoxene. Two generations of felspar are visible in some slides, one comprising as immense profusion of minute needles, the other composed of lath-shaped crystals of decomposed plagioclase, mostly labradorite of some size. The felspar phenocrysts are sometimes stellately grouped, and cruciform twinning is occasionally seen. Augite is abundant; the crystals show much corrosion and often exhibit twinning. Magnetite seems to have been plentiful in the fresh rock and well-shaped crystals of epidote are not uncommon. Olivine has not been detected. A frequent constituent of the amygdules is quartz, sometimes with a lining of epidote; the quartz may show liquid cavities with movable gas bubbles. Delessite, viridite, scolecite and calcite are other material found filling the amygdules.

The traps of Mandi are probably continuous with a volcanic band observed by Dr. West north of Simla. At Kaslog the rock, whose outcrop is here nearly a mile in width, is sufficiently unaltered to be recognised as a volcanic rock; southwestwards, its thickness decreases until the outcrop is cut out by the Shali thrust, while east of Kaslog at Tatapani, it becomes reduced to a few feet and takes the metamorphosed form of a chlorite schist.[2]

Dalhousie Area, Chamba.—Thrust over the Murree and Siwalik Tertiary belt in the Dalhousie area, and overlain by beds of the Chail series, is a thin bed of igneous rock which, though fresher than the average type, may belong to the Panjal Trap; its equivalence to one of the Dras rocks (Cretaceous to Eocene) is also a possibility. Southeastwards, it dies out and the Chails are seen resting on the Tertiaries.[3] The sequence in Chamba State which McMahon regarded as Silurian and Carboniferous in age is assigned by West to the Chail series.[4]

Simla, Chakrata, Tehri Garhwal and Garhwal.—Among the doleritic and basaltic intrusions found among the unfossiliferous Himalayan rocks of the Simla and Chakrata area, it is difficult to decide whether they are of pre-Cambrian age or whether they belong to the Panjal or to the Dras suite; the latter is more or less equivalent to the Deccan Trap. As Dr. Auden remarks, in the present state of our knowledge, it would be almost as logical to deduce the age of the rocks penetrated by these intrusions as to deduce the age of the intrusions from that of the rocks they penetrate. Amygdaloidal andesites and related intrusive diabases have been found by Auden associated with quartzites and limestones of possibly Permian age in Tehri Garhwal and Garhwal. These extrusive and intrusive rocks may be equivalents of the Panjal traps[5] or they may belong to the later Dras or Deccan suite.

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[1] *Rec.*, XV, 155-164 (1882).

[2] *Rec.*, 73, 96 (1938).

[3] *Rec.*, LXIX, 77 (1935).

[4] *Rec.* XIV, 306 (1881); *Ibid.* XVI, 37 (1883); *Ibid.* XVIII, 82 (1885); *Ibid*, LXIX, 76 (1935).

[4] *Rec.* LXIX, 134 (1935); *Ibid.* 73, 100 (1938).

Eastern Afghanistan and Russian Turkistan.—In actual age, the Doab volcanic series of eastern Afghanistan spans a period considerably later than that of the Kashmir Panjal volcanics ; for that and other reasons it will be described under the heading of Gondwana (Rajmahal Trap). Griesbach's plant bearing series further west has associated volcanic rocks and probably includes representatives of the Doab.

In Darwaz and other parts of Russian Turkistan, a similar volcanic series exists but here, unlike the Afghan area, the lowest beds are interstratified with the Fusulina limestones and approximate more closely, therefore, to the Panjal in actual age.

Central Tibet.—Lavas and ashes very similar in appearance to those of the Panjal Volcanic system have been observed by Sir Henry Hayden between Shen-tse Dzong and Nan-dzum in Tibet, and persist almost as far as Mi-bar. Between the Pa-ro Tsang-po river and Chu-tra-ri, thin bedded, flaggy sandstones, not much altered, are described as lithologically resembling Gondwana beds.[2]

LOWER GONDWANA OCCURRENCES OF KASHMIR.

Distribution and Stratigraphical position.—The discovery within the Himalaya of the Glossopteris flora, one of the most important features, as we shall see, of the lower half of the great Gondwana system of Peninsular India, was first made by Dr. Noetling in 1902 at Khunmu in the Vihi Valley, fifteen miles southeast of Srinagar.[3] Lower Gondwana plant beds, accompanied by marine Permian sediments up into which they appear to pass, have been found on various spurs overlooking the Vihi plain, both on its northwest and southeast sides, and in the hills to the east ; an outcrop of them curves interruptedly round the northwest angle of the western peak of Panjal Trap (9,707 feet), and has been traced thence northwards beyond Narastan. Similar Gondwana rocks have also been found along the southern edge of the Kamlawan peak of the same trap further to the southeast, near Pailgam in the Lidar valley, in the Nagmarg area north of the Wular lake, and in the Pir Panjal. The importance of these discoveries lay in the stratigraphical position of the plant-bearing strata below limestones with well-known Salt Range fossils of Permian age, disproving an early suggestion that the earliest Gondwana horizons belong to the Jurassic.

The Gondwana plant beds of Kashmir occur as often above as they do below Panjal Traps ; in view of the shifting inconstancy of these lavas as regards their horizon, this variation in relative position has no taxial significance. According to Wadia, the matrix of these plant beds is without exception of volcanic origin and therefore an integral part of the Panjal Volcanic series. The plant beds may, in fact, be looked upon as belonging to the Agglomcratic Slate series and chiefly to the middle and top thereof.

Vihi District.—On the Risin spur, the Gondwana beds are composed largely of tuffs and occur with a winding irregularity of strike but in a normal manner between the Panjal Trap, down into which they pass rapidly but not abruptly, and the Zewan beds of Lower and Middle Permian age.[4] Resting on the trap which is here amygdaloidal, the lower beds of the series consist of shales, impure

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[1] *Mem.*, XXXIX, 78, (1911).

[2] *Rec.*, LXVII, 334 (1933).

[3] *Gen. Rep.*, 1902-3, 23.

[4] D. N. Wadia, *Rec.*, LXI, 143 (1928).

in places, followed by black crystalline limestone silicified sometimes to black chert; above come beds originally described as carbonaceous shales but since shown to be glassy volcanic tuffs of an extremely pure type and for the most part finely laminated, in which fragments of *Gangamopteris* fronds have been identified, with occasional thin bands of black crystalline limestone.[1] Next come beds of limestone and chert, and finally more black, slaty tuff, in which have been found the plants, *Gangamopteris kashmirensis* Sew., *Cordaites* sp. (probably *hislopi*), and *Psygmophyllum* (?) sp., the fishes *Amblypterus kashmirensis* Woodw. and *A. symmetricus* Woodw., and the labyrinthodonts, *Archegosaurus ornatus* Woodw. and *Actinodon risinensis* Wadia & Swinton.[2]

A mile or so to the northeast, in the Guryul ravine, the *Gangamopteris* beds are very thin compared with those on the Risin spur, and comprise 6-10 feet of a white chalcedony (novaculite) lying upon amygdaloidal trap, surmounted by alternating "shale" and chert, some, if not all, of the former being glassy tuff and containing badly-preserved *Gangamopteris* remains. As compared with the Risin spur exposure, chert is more abundant and limestone almost absent. The beds are overlain by Zewan shale and limestone with bryozoa and brachiopods.[3] Although there is no discordance between the two formations, the rapid reduction in thickness of the Gondwana beds is suggestive of overlap, a suggestion supported by the discovery in one part of the ravine of the *Protoretepora* bed, the basal horizon of the Zewan stage, directly superposed upon a cliff of the Panjal Trap with a mere trace of the novaculite between.[4]

On the Zewan spur, about two miles west of the Risin spur, the highly dipping *Gangamopteris* beds are over 200 feet thick. The lowest member is the white novaculite, which can be seen passing laterally into a limestone. Hayden has, in fact, shown that the original rock was an oolitic limestone which together with the associated shales and sandstones has suffered partial silicification, the nuclei of the grains in these cherts were probably the tests of foraminifera, such as *Endothyra*, or plant fragments. The rest of the sequence consists of shales—some of them siliceous, some pebbly—black tuff, chert and limestone, with a topmost bed of dark-coloured grit, the whole conformably followed by the Zewan beds. Black glassy tuffs near the base carry *Gangamopteris kashmirensis* Sew. in abundance, *Psygmophyllum hollandi* Sew. and *Cordaites* (probably *hislopi*). The cherts, including the novaculite which is nothing more than a bleached chert were probably the products of Panjal volcanic activity. The silicification which the cherts illustrate lasted throughout the *Gangamopteris* stage but is not seen in the following Zewan beds; that it was proceeding during the early part of the *Gangamopteris* period would appear from the fact that pebbles of a chert exactly like that of the main band at the base of the stage occur in a pebble-bed low down in this section. From these Gondwana shales or tuffs Dr. Terra has obtained the labyrinthodon, *Lysipterygium deterrai* Branson.[5]

On the eastern and southeastern edges of the Vihi plain, the *Gangamopteris* beds are absent; at Rechpura, on the east, the lowest limestone of the Zewan lie directly upon the Trap, but with no discordance.

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[1] The tuffs which contain neither clay nor carbon, are wholly composed of glass particles with a few tiny crystals of felspar; the black colour is said to be due to iron and bleaches rapidly on exposed parts.

[2] *Rec.*, LXI, 141-145 (1928).

[3] H. H. Hayden. *Rec.*, XXXVI, 26-27 (1907).

[4] C. S. Middlemiss. *Rec.*, XXXVII, 306 (1908).

[5] *Mem. Conn. Acad.*, IX, Art. II, 23 (1935).

On two small spurs to the south of the Trap peak of Kamlawan (8,588 feet), to the north of Islamabad, 200-300 feet of black glassy tuffs and siliceous shales with a few limestones are seen directly above massive trap. As at Risin and Zewan, the tuffs and shales weather white, and are frequently silicified, as are also some of the limestone beds. Plant impressions, including a doubtful *Gangamopteris*, have been found in the shales. The sequence here differs from the others by the fact that these plant-bearing beds are overlain by 200-400 feet more of the trap and fine ash beds ; these volcanic beds, if the section be a normal one, would appear to take the place of the lower part of the Zewan stage, since they in their turn are followed by massive grey bryozoan limestone with *Camarophoria.*

At Mandakpal, the bed of novaculite is seen, but there are no siliceous shales or black tuffs with *Gangamopteris.* The novaculite is not observable a little to the southwest. but further on reappears on the Ludu spur where it is followed by Panjal volcanics ; traces of it are visible on another spur a mile to the south. On the Barus spur one-and-a-half miles further south, overlooking the Jhelum, about 100-200 feet below the uppermost Trap beds, is an interbedded band of dark limestone, 10-20 feet thick, with obscure traces of fossils. It conforms in dip to the rest of the section, and is associated with some quartzitic and shaly material. Upon the Panjal Trap above rest some much mixed layers of novaculite and limestone followed by cherty shales and a grey limestone full of a *Productus* of the *lineatus* group ; next comes a flaggy limestone with another small *Productus*, and a bed containing crinoid stems, which is capped by the *Protoretepora* bed poorly exposed.[1]

Above the Nishat Bagh in Srinagar are to be seen 200-300 feet of fine slate with obscure plant-impressions, becoming quartzitic at the junction with the Panjal Trap which contains 'suleimanite'.

Nagmarg area.—In the Nagmarg area, to the east of Hundwara, many good sections are exposed in the forest paths, leading from the Lolab river to the Wular Lake. The following generalized sequence was observed by Wadia lying unconformably upon trilobite beds of Cambrian age.[2]

Panjal Trap, bedded and amygdaloidal,

Black, massive, shaly and gritty tuff, with fragments of *Gangamopteris* and *Glossopteris*
Quartzitic agglomerate and sandstone.

Grey and brown, coarse, soft sandstone with slaty beds containing several species of *Productus, Spirifer, Syringothyris, Fenestella* and *Protoretepora.*

Amygdaloidal lava flows.

Agglomeratic Slate, containing pebble and angular foreign fragments.

Brown and grey sandy beds.
Conglomeratic sondstones, consisting of rounded pebbles of silicious rocks in matrix of loosely cemented sand.

unconformity.

(Cambrian rocks).

Pir Panjal.—The peak of Tatakuti in the Pir Panjal, made up of Agglomeratic Slate dipping steeply to the northeast, is followed in this direction by an enormous thickness of Panjal Trap, upon which rest about 200 feet of characteristic Lower Gondwana carbonaceous shales or slates and dark quartzitic grits. Amongst the shales and slates occur the fronds of *Glossopteris, Gangamopteris, Psygmo-*

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[1] C. S. Middlemiss. *Rec.*, XXXVI, 317 (1908).

[2] *Rec.* LXVIII, 154 (1934).

phyllum (?), *Alethopteris* (?) and other plant fragments. These Lower Gondwana beds are overlain by the Zewan beds of Lower Permian age.[1]

At Apharwat, some four miles southwest of Gulmarg, Lower Gondwana plants have been found in contact with the Tanawal beds, and are said to pass into the Agglomeratic Slate.[2] Here the section consists of about six feet of a basal conglomerate of trap pebbles, perhaps a representative of the Talchir conglomerate followed by purple and dark-coloured shales with *Gangamopteris*, *Glossopteris*, *Cordaites*, *Tæniopteris*, and *Alethopteris* cf. *phegopteroides* Feistm.

The occurrence at the Golabgarh Pass forms part of a separate outlier échelonned on the main belt to the southeast and lying in the Agglomeratic Slate and the Panjal Trap. At the Pass, the Gondwana beds, including plant-bearing members, lie between the Panjal Volcanics below and the Zewan beds above in a tight synclinal fold striking generally N.W.-S.E. The sequence here comprises (i) a basal conglomerate lying on the Panjal Trap and ash beds, (ii) succession of siliceous shales, quartzites, carbonaceous shales and sandstones with a Lower Gondwana flora, (iii) soft, earthy calcareous sandstones and limestones with a typical Zewan fauna corresponding closely with the Guryul ravine section, and (iv) a thin-bedded blue-grey unfossiliferous limestone which is probably the equivalent of the Triassic beds found in the Guryul ravine. The Gondwanas of this area form a contrast in their thin-bedded character and occasional dark colour to the massive, enormously thick and frequently pale-weathering Panjal Volcanics, the strong basal conglomerate cropping out precipitously above the succeeding and more easily weathered shales.

The pebbles of the basal conglomerate, ranging up to the size of racquet balls, consist chiefly of compact, grey, chert-like rocks, the rest being of dark slate fragments with a sprinking of small quartz grains. The bed shows no indications of discordance with the underlying trap.[3] This conglomerate, the homotaxial equivalent of the basal Talchir boulder bed, has so far showa no signs of glaciation. In other words, the glacial phase of the Lower Gondwana in Kashmir, as in Spiti, appears to be represented by a conglomerate differing in no way from a normal conglomerate with water-worn pebbles. Bed No. (ii) of the above sequence comprises about 180 feet of thin-bedded siliceous shales and carbonaceous shales, followed by some 400 feet of hard, grey sandstones, sometimes almost quartzitic, interbedded with numerous shaly horizons. One of the shale bands is crowded with plant remains, some of them well preserved, consisting mainly of *Psygmophyllum haydeni* Sew., *Glossopteris indica* Schimp., *Cordaites hislopi* Bund., and a doubtful *Gangamopteris kashmirensis* Sew. have also been recognised.[4] In a higher shale band, *Glossopteris* is the prevailing genus, (*G. indica*) having been identified, as well as numerous examples of *Vertebraria indica* Royle and a doubtful *Callipteridium*. There is no discordance, the sequence being a normal consecutive superposition of beds passing by gradation from one into the other, with no stratigraphical break and no sudden variation in dip angle, up into the overlying marine beds which form the base of the Zewan series.

Flora and fauna of the Plant Beds.—The flora and fauna of the Kashmir Plant beds, although so meagre, is of considerable interest. *Glossopteris indica* and *Vertebraria indica* are species which range from the Talchir to at least the end of the Damuda, probably to the end of the Lower Gondwana. *Gangamopteris* is typical of the lowest horizons of the Gondwana system in India and of its equivalents in foreign countries. *Psygmophyllum*, a genus foreign to the *Glossopteris* flora of the southern hemisphere and a typical northern form, is consistent with any horizon from Lower Carboniferous to Permian. The exact significance of this statement will appear in a later chapter ; suffice it to say here that *Psygmophyllum* is well represented in the northern continent of Angaraland which stretched from the Urals to the Pacific. The only other species of this genus known definitely to occur in Gondwana strata is *P. kidstoni* from the Lower Karroo beds of Vereeniging in South Africa. *Cordaites* has much the same range as *Psygmophyllum*. The *Callipteridium* has been compared with another northern form, the Permian species *Callipteris conferta* Brongn.[1] Prof. B. Sahni notes the close similarity of *Gangamopteris kashmirensis* to a foreign immigrant in the Angara flora, "*Glossopteris angarica*", which he believes to be a *Gangamopteris*.[2] The fishes and the labyrinthodont *Archegosaurus ornatus* belong to typically Lower Permian horizons, though *Amblypterus* has been found in the Coal Measures of France and Belgium There is nothing against either a Talchir or lowest Damuda (Karharbari) age for these beds[3]. There are here indications of a more equable climate than that which prevailed in the interior of the Gondwana continent.

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[1] C. S. Middlemiss. *Rec.* XLI, 124-25 (1911).

[2] *Rec.*, 72, 77 (1937).

[3] C. S. Middlemiss. *Rec.*, XXXVII, 292 (1908).

[4] A. C. Seward. *Pal. Ind.*, New Ser., Vol. IV., *Mem.* 3, p. 2 (1912).

PERMIAN MARINE SEQUENCE IN THE PUNJAB HIMALAYA AND EASTERN KASHMIR.

Spiti and Rupshu.—The Kuling system is a term adopted by Hayden for the sequence following unconformably the Kanawar system in Spiti and succeeded by beds with Lower Triassic fossils. The basal conglomerate of the Kuling was regarded by McMahon and R. D. Oldham as the equivalent of the Blaini conglomerate of the Simla area, but this correlation has never been definitely substantiated and Hayden prefers to assign it to the base of the Permian and speaks of it always as the Permian conglomerate. Accepting this assignment, the Kuling becomes synonymous with the Permian system ; it may be subdivided as follows :—

Kuling System	(c) Productus Shales[4] .	(ii) *Xenaspis* & *Cyclolobus* stage. (1) *Marginifera himalayensis* stage.	Upper Permian.
	b) Calcareous Sandstone, with *Spirifer musakheylensis* and *S. marcoui*.		Middle Permian (transgressing into Lowor Permian).
	(a) Conglomerate and Sandstone.		Lower Permian.

The lowest or Conglomerate and Sandstone series marks the position of a great unconformity extending from Spiti to Kumaon, a break in sedimentation which is represented in parts of Kashmir by the lower horizons of the Panjal Volcanic beds. This Spiti conglomerate, though not itself known to be a glacial deposit, was thought at one time to be the Blaini conglomerate and, therefore, of Talchir or Upper Carboniferous age. Elsewhere, however, what are believed to be its equivalents occur stratigraphically above plant beds which are not older than Upper Carboniferous and may even represent the lowest Permian. The Conglomerate and Sandstone series varies in character and thickness, and high up on the slopes between Lanjarse and Po, and again in a section above Pomcrang a few miles further west, it has the appearance of passing down into the Fenestella Shales; the latter here contain near their upper limit beds of grit and 20 feet of a coarse conglomerate which is overlain by another bed of shale followed by a great thickness of grit, quartzite and conglomerate, belonging to series (a)[1]. The grits, which may be coarse or fine, consist of angular and rounded fragments of shale and limestone embedded in a coarse slaty matrix. The conglomerates comprise boulders and pebbles of various sizes, ranging up to a foot across, embedded in gritty or sometimes a slaty matrix.

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[1] *Pal. Ind.*, New Ser., Vol. IV, Mem. 3, p. 4- 5 (1912).

[2] *Proc.* 13th *Ind. Sci. Congr.*, 241 (1926).

[3] Omitting the suggested presence of *Ginkgo*, which is probably a mistake.

[4] Corresponding to Stoliczka's "Kuling series" with some Triassic rocks removed from above and some Carboniferous from below Stoliczka's "Kuling Shales" include the Productus Shales, (*c*), and some Lower Triassic shales of rather similar appearance in Spiti. The classification has been further confused by Lydekker who mapped tho Syringothyris limestone series in Kashmir under the Kuling system though now proved to be separated therefrom by many thousands of feet of Fenestella Shales, Agglomeratic Slate and Panjal Trap.

These grits and conglomerates, in a crushed condition, have been recognised, in Rupshu, eastern Kashmir. Here they are well exposed in the Pang-po river and the valley of the Chepzi, and can be traced along the hills on either side of the Para river near Chepzi[2]. They are succeeded by the Calcareous Sandstone series (*b*) in the form of calcareous schists and crushed limestones full of crinoid stems; this series is well exposed in the Para river near Sitang Gongma, and is followed by dark slates containing badly crushed but recognisable Productus Shale fossils.

In lower and upper Spiti and in Kanawar, the two upper subdivisions (*b*) and (*c*), are underlain by the conglomerates of the basal subdivision; in other parts of this region they rest on the Ordovician quartzite or, as in the Thanam valley, on the Silurian limestone, or again, as in the Pin valley, on the *Syringothyris* Limestone. The calcareous sandstone of series (*b*) is in its lower part coarse and conglomeratic. It is everywhere fossiliferous, but the fossils are badly preserved; the following forms have been identified by Dr. Diener from this fauna, which is poor in species though rich in individuals.[3]

Spirifer (*Neospirifer*) *musakheylensis* Dav. (probably including Reed's variety *humilis*)
,, ,, *nitiensis* Dien.
,, ,, *marcoui* Waag.,
,, *distefanii* Gemm.,
Athyris (*Cleiothyridina*) *gerardi* (Dien) ("*Spirigera gerardi*"),
Dielasma latouchei Dien.,
Kiangsiella Cf. *pectiniformis* (Dav.) "*Streptorhynchus pectiniformis*", (Perhaps identical with Reed's *Meekella* (?) cf. *eximiaeformis* (Touza) from the Upper Productus Limestone,
Aulosteges cf. *gigas* Netsch.,
Blanfordinia subeotica (Waag) (An Upper Productus Limestone species),
Aviculopecten sp.

Four out of these ten forms have been found in the Salt Range Productus Limestone. Of these, *Spirifer marcoui* is restricted to the Lower division of the latter formation; *Athyris gerardi*—described as the commonest leading foosil in the Kuling Calcareous Standstone—is confined to the Upper Productus Limestone;

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[1] H. H. Hayden. *Mem.* XXXVI, 51 (1904).
[2] *Mem.*, XXXVI, 93. (1904)
[3] *Pal. Ind.*, Ser. XV, Vol. 1, Pt. 5, p. 196 (1903).

and *Spirifer musakhcylensis* and four varieties of *Kiangsiella pectiniformis* are characteristic of the Middle or Upper Productus Limestone. The evidence, therefore, is not quite clear as to what part of the Permian the Calcareous Sandstone belongs.[1] If importance is attached to the presence of *Spirifer marcoui*, a very distinctive and easily recognisable species, part at least of this subdivision (*b*) would fall within the Lower Permian, but most of its affinities appear to be with the Middle Permian.

Throughout Spiti and Bashahr, the Calcareous Sandstone series is invariably overlain by a bed, usually from 100 to 150 feet thick, of black or dark brown, often siliceous, shale, with a few thin irregular partings of hard, brown, concretionary sandstone near its base. This formation, which has been called the Productus Shales, owing to the predominance therein of brachiopods originally referred to the genus *Productus*, extends with little variation throughout a large section of the Himalaya, from Kashmir to the Nepal frontier and probably beyond. Its stratigraphical position is between the Calcareous Sandstone below and a ferruginous limestone of Lower Triassic age containing the zone of *Otoceras woodwardi* above, its limits everywhere being clearly defined; an excellent section of it is exposed on a small ridge behind the village of Kuling in Spiti where it is overlain by the Lower Trias including the *Otoceras* beds.

Throughout Spiti and Bashahr, fossils in the Productus Shales are numerous though belonging only to a few species; the lower part of the series especially contains numerous brachiopods which occur in both the shale and the sandstone partings. In addition to a few bryozoa and badly preserved plants, the following species have been recognised by Diener.[2]

Marginifera himalayensis Dien.
Productus cf. *gangeticus* Dien.
Chonetes cf. *lissarensis* Dien.
Athyris (*Cleiothyridina*) *gerardi* Dien.
Spirifer (*Spiriferella*) *rajah* (Salt.).
,, (*Neospirifer*) *musakhaylensis* Dav.
,, ,, cf. *nitiensis* Dien.

Throughout the shale occur numerous concretions, both isolated and in bands but rarely fossiliferous; some 30 feet below the top, however, is a band of such concretions containing ammonoidea which consist chiefly of *Xenaspis* cf. *carbonaria* Waag. and *Cyclolobus* cf. *oldhami* Waag.; less frequent are *Cyclolobus insignis* Dien., *C.* (*Krafftoceras*) *kraffti* Dien. and *C.* (*Krafftoceras*) *haydeni*.[3]

The age of the Productus Shales is indicated by their position immediately below Triassic beds, as well as by their similarity to the unquestionably Permian strata of Painkhanda and Johar, while their intimate connection, both stratigraphically and palaeontologically, with the underlying Calcareous Sandstone, favours the inclusion of the latter in the same system.[4] There is little doubt that the Productus Shales are a somewhat different faunistic facies of the Upper Productus Limestone of the Salt Range, to the higher horizons of which the stage of *Xenaspis* cf. *carbonaria* and *Cyclolobus* cf. *oldhami* would correspond.

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[1] Noetling correlated it with the Middle Productus beds, perhaps because he employed Waagen's old scheme of subdivision. It is not impossible that collections have become mixed.

[2] *Mem.*, XXXVI, 54 (1904) and *Pal. Ind.*, Ser. XV, Vol. I, Pt. 2, 86 (1899).

[3] Described in *Rec.*, XXXI, 56 (1904).

[4] H. H. Hayden. *Mem.*, XXXVI, 56 (1904).

Changchenmo valley.—North of Rupshu, in the Changchenmo valley, a thrust block of Lower Permian limestone has yielded the trilobite, *Paraphillipsia karpinskyi* Toum., a species found in the "Permo-Carboniferous" (Artinskian) of the Crimea, and a new species, *P. pahari* Weller.[1] It is described as reddish-grey coralline limestone, and is underlain by a red limestone carrying *Productus* and bryozoa.

Karakoram.—Along the lower Sarpo Laggo and Shaksgam valleys, on the north side of the Karakoram, in north Kashmir, Desio discovered fossiliferous "Permo-Carboniferous" or, as we are calling them, Lower Permian beds. In the Biafo-Baltoro region, on the southern slopes of the range, these rocks are associated with gneisses and show a high degree of metamorphism. These metamorphosed pelitic and calcareous sediments are exposed in force between Pakore and Chongo and are also seen near Tungmo, occupying at least a portion of Mt. Koser Gunge (21,000 feet). To this formation probably belong the marbles which have been observed near Askole and up the Biafo glacier[2]; among the rocky types met with by Auden are garnetiferous chloritic phyllite, diopside actinolite-granulite, tremolite-and actinolite schist, marble, calciphyre, calc-granulite, actinolite, epidote gneiss, amphibolite, and a striking rock made up of large garnets in a matrix of kyanite, staurolite and a mineral resembling the vanadium mica, roscoelite. The beds are in places intruded by a biotite gneiss or by a network of pegmatite dykes and sills. Such rocks are seen not only in the Baltoro basin but also in the Siachen valley adjoining to the southeast; the Productus beds in the upper Siachen have yielded *Derbyia grandis* Waag.

Rocks of this age are seen not only in the Baltoro basin but occupy most of the northern slope of the Masherbrum-Bride chain up to the Chogolisa saddle,[3] and the greater part of the Panmah basin. The gigantic tops of Broad and Gashserbrum (26,360 feet) are formed of this limestone, grey and black in colour, occasionally schistose, and containing lamellibranchs, gastropods and corals in association with the foraminifer, *Neoschwagerina*. Thin vertical wedges of this limestone enclosed within gneiss, were found by Auden crossing the upper part of the K² glacier and occurring at the foot of the northern face of K¹ peak. The greater part of K² peak is, however, composed mainly of augen gneiss.

This series, in its unmetamorphosed form of grey limestone and black calcareous shales, called by Auden the Shaksgam series and found along the northern slope of the Karakoram range, has yielded fossils in the Lower Sarpo Laggo valley and the Shaksgam valley; in the latter area the rocks are frequently rich in Lower Permian fossils.[4] The fossils include : *Parafusulina shiptoni*, *Polypora* sp., numerous *Productus*—among them *P.* (*Echnioconeba*) *punctatus* and *P.* (*Echnioconeta*) *pustulosus*—*Dielasma* sp., *Reticularia* (including *R. lineata*, perhaps the eqivalent of *Squamularia punjabica* Reed), *Martinia* related to *M. dispar*, a form found in the Plateau Limestone of the Shan States of Burma.[5] The *Parafusulina shiptoni*, n. sp., has recently been described by Carl O. Dunbar, who states that it is unquestionably of Permian age, and is more advanced than any species in the Artinskian.[6] Auden suggests that the Shaksgam series is probably equal to the lower part of Hayden's Pamir Limestone.

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[1] J. M. Weller. *Mem., Conn. Acad.*, IX, Art. III. 31 (1935).

[2] J.B. Auden. *Rec.*, LXIX, 131 (1935).

[3] A Desio. *Geogr., Journ.* LXXV, 402 (1930).

[4] K enneth Mason. *Himalayan Journ.*, X, 43 (1938).

[6] *Rec.*, LXXV, Prof. paper No. 5 (1940).

From the Remo valley, due east of the Siachen, and from Depsang, southeast of the Karakoram Pass, both localities on the northeastern flank of the Karakoram, have been collected the following Middle and Upper Permian brachiopods.[1]

Productus (*Ruthenis*) *purdoni* Dav.,
Lyttonia nobilis Waag.
Spirifer (*Neospirifer*) *musakheylensis* Dav.,
Marginifera himalayensis Dien. (predominant).
Syringothyris lydekkeri (Dien.),
Martinia glabra, (Mart.) ?
Enteletina acutiplicatus Waag. ?
Spirigerella (?) sp.
Uncinunellina theobaldi (Waag.),
Camarophoria humbletonensis Howse.?
Notothyris sp.
Enteletes waageni Gemm.[2]

To this horizon belong a few specimens collected from fragments of black limestone found near the crest of the chain, *viz.*, *Marginifera himalayensis* Dien, *Spirifer* (*Elivina*) *tibetanus* Dien. and *Productus* (*Linoproductus*) *aagardi* Toula.

From near the source of the Shyok two horizons can be made out, the lower varying in character from schists, limestones and marls, and equivalent to that mentioned in the previous paragraph. This horizon would appear to correspond to the lower of the two zanes of the Himalayan Productus Shales, and has yielded the following fauna[3] :

Brachiopoda.—
Productus (*Linoproductus*) *aagardi* Toula,
  ,, (*Linoproductus*) *tenuistriatus* de Vern.,
  ,, "*semireticulatus*" Mart., (*Dictyoclostus*)
  ,, (*Echinoconcha*) *punctatus* Mart.,
  ,, (*Avonia*) *curvirostris* Schellw.,
  ,, *incisus* Schellw.,
  ,, *gruenewaldti* Krot.,
Marginifera himalayensis Dien. (predominant),
Spirifer (*Elivina*) *tibetanus* Dien. (common),
  ,, ,, *interplicatus* Rothpl.,
  ,, (*Paeckelmannella*) *niger* Waag.,
  ,, *bisulcatus* Sow.,
  ,, aff. *lydekkeri* Dien.,
Spiriferina (*Mansuyella*) *ornata* Waag.,
Spiriferina multiplicata Waag.,
Camarophoria mutabilis Tschern.,
  ,, ,, var. *biplicata* Stuck.,
  ,, *superstes* de Vern.,
  ,, *crumena* Mart.
Streptorhynchus cf. *pectiniformis* Waag.,
Orthis (*Schizophoria*) aff. *supracarbonica* Tschern.,

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[1] C. F. Parona. *Atti. R. Acad. d. Sci. d. Torino*, LXVII, 179 (1932); *Pal. Ind.* New Ser. Vol. XXXI, *Mem.* 1, p. 63 (1941).
[2] De Terra. Pal. in Wissen Ergebn. Trinkler, Zentralasien Exped. Bd. II p. 159 (1932).
[3] Gortani. *Atti. Acc. Linci*, Ser. Vol. XXIX, pp. 53-55 (1920).

Brachiopoda—*contd.*

Martinia applanata Waag.,
Hustedia remota Eichw.,
Hustedia indica Waag.,
? *Martiniopsis convexa* Tschern.,
Hemiptychina pseudo-elongata Schellw., (*Beecheria ?*)
,, *sublaevis* Waag.,
Notothyris nucleolus Kut.,
,, *exilis* Gemm.,
,, *simplex* Waag.,
,, cf. *pulchra* Gemm.,
Athyris subexpansa Waag.,
Pugnax osagensis Shum.,
Dielasma aff. *elongatum* Schloth.

Lamellibranchiata.

Lima aff. *retifera* Shum.

In the same area, the upper or *Xenaspis* horizon of the Productus Shales appears also to be present in the form of a limestone which has yielded.[1]

Orthothetes armeniacus Arth.,
Streptorhynchus (?) aff. *shanensis* Dien.,
Chonetes variolata d'Orb. (predominant),
Productus (*Linoproductus*) *lineatus* Waag.,
,, (*Waagenoconchia*) *abichi* Waag.,
Marginifera spinoso-costata Abich (predominant),
Strophalosia longa Nec.

From an equivalent horizon south of the Karakoram Pass, *Xenodiscus* itself has been collected.

The Zewan beds and Productus Shales of Central Kashmir.—In the various exposures of the Vihi area, the *Gangamopteris*-bearing band is succeeded by a calcareous succession passing up into a shaly series which is in turn overlain by the Trias. The term "Zewan" was at first given to the calcareous succession but subsequently extended to embrance also the shaly series; it thus included everything between the *Gangamopteris* beds and the Trias. The shaly series, however, is unquestionably the representative of the Productus Shales of Spiti and Kumaon, and it seems wiser to restrict the term Zewan, if it is to be retained, to its original limits, *i.e.*, to the calcareous succession. The latter must obviously correspond to the older portions of the Kuling system and include the "Calcareous Sandstone" of the Spiti area. In this work the term "Zewan series" will be used for that part of the Kuling system in Kashmir which underlies the Productus Shales; it is probably of Lower and Middle Permian age.

Along the north-eastern side of the Pir Panjal, Middlemiss has mapped a broad outcrop consisting of Upper Triassic limestones bounded on each side by narrow bands of Gondwana and Permian rocks, stretching from Tosh Maidan, where it is faulted against the Panjal Trap, to the Golabgarh Pass, a distance of some thirty-eight miles, and probably beyond; here the Permian consists of the Zewan series overlain by what must be younger representatives of the Kulings. At the Golabgarh Pass itself, a syncline of the Panjal Volcanics enclose a succession including the following: Four hundred feet of Lower Gondwana siliceous and carbonaceous slates with fragments of plants including *Gangamopteris* and *Glossopteris*; earthy, calcareous sandstones, sands and shales with brachiopods, and a dark, thin-bedded limestone with *Protoretepora ampla*, all belonging to the Zewan series; over 300 feet of Productus Shales, here represented for the most part by earthy, micaceous sandstones; an inner core of Triassic limestone. Limestone intercalations are seen in the Volcanics, some of them obscurely fossiliferous.[1] In the Vihi area, the Zewan beds consist of a basal 60 feet of dark grey, sandy limestone with compacted layers of brachiopods, followed by 30 feet of dark sandy shales and thin interbedded limestones full of colonies of the bryozoan, *Protoretepora*, one above the other. The brachiopods in the lower of these two zones are for the most part unidentifiable in the Vihi sections, but from some of them and more especially from the equivalent horizon at Golabgarh, consisting of some 200 feet of earthy calcareous sandstones and shales, introducing the marine phase of the Permian after the *Gangamopteris* land period, the following brachiopods have been recognised by Diener:

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[1] Perhaps not all from the same level.

Productus (*Linoproductus*) *cora* d'Orb.,
  ,, (*Ruthenia*) *purdoni* Dav. (Probably including Reed's variety *prolonga*),
  ,, *gangeticus* Dien.,
Marginifera spinosocosta Ab. (perhaps equivalent to Reed's *M. protracta* from the Lower and Middle Productus Limestone).

Spirifer (*Neospirifer*) *musakheylensis* Dav.,
Spirigerella derbyi Waag.,
Camarophoria purdoni Dav.,
Hemiptychina himalayensis Dav.
  " *sparsiplicata* Waag., var. *intermedia* Reed.

In spite of its scantiness this fauna can be recognised as typically Permian[2].

The fauna of the upper or *Protoretepora* zone, although extremely rich in individuals is very poor in species, only the following having been definitely determined beside a doubtful specimen of *Derbyia*:

Bryozoa—
  Protoretepora ampla Lonsd.

Brachiopoda—
  Lyttonia nobilis Waag.,
  Spiriferina (*Spiriferellina ?*) *zewanensis* Dien.
  Spirigerella derbyi Waag. var, *acutiplicata* Waag.

The remarkable species of brachiopod *Lyttonia nobilis*, is sometimes found beautifully preserved; it is not strictly confined to this horizon but it is not found elsewhere in such great abundance.

The limestone of the lower zone of the Zewans in places has undulating surfaces like irregular ripple-marking.[3] There is no evidence of unconformity between the *Gangamopteris* beds and the Zewan series. At Rechpura, the lowest limestones of the Zewan series lie directly upon the Panjal Volcanics and the plani beds are not present, but if there is any unconformity at all it is probably little more than that due to local disturbance in a volcanic area.[4]

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[1] *Gen. Rep. Rec.*, LXXII, 76 (1937).
[2] *Pal. Ind.*, New Ser., Vol. V, Mem. 2, 107 (1915).
[3] C. S. Middlemiss. *Rec.*, XXXVII, 298 (1908).
[4] H. H. Hayden. *Rec.* XXXVI, 32 (1907)

In the hills to the east of Vihi, *i.e.* northeast of the Wastarwan mass, the *Protoretepora* zone appears to be absent, since it could not be found at either Pastannah, Lam or Narastan ; a dying out of the Zewan beds eastwards is thus suspected.[1]

In the Vihi area, the top of the Zewan beds is characterised by a well-marked limestone ; this may be regarded either as the uppermost horizon of the Zewan or the lowest of the Productus Shale series, here somewhat more calcareous than in Spiti. It has not been recorded from the Pir Panjal, and has been spoken of as the zone of *Productus indicus* ; it has yielded the following :

Lamellibranchiata—
    Aviculopecten cf. *hiemalis* Salt.

Brachiopoda—
    Productus (*Dictyoclostus*) *indicus* Waag. (probably Reed's variety *paucicostata* from the Upper Productus Limestone),
        ,, ,, *spiralis* Waag. (probably including *P.* (*D.*) *transversalis* Tschern.),
        ,, (*Waagenoconcha*) *abichi* Waag.,
        ,, (*Linoproductus*) *cancrini* de Vern.,
        ,, ,, *cancriniformis* Tschern.,
        ,, (*Haydenella*) *vihianus* (Dien.),
        ,, *gangeticus* Dien.,
        ,, *narastanensis* Dien. (from the Narastan locality ; closely allied to *P.* (*Dictyoclostus*) *transversalis* Tschern.),
        ,, aff. *porrectus* Kut.
    Marginifera himalayensis Dien.,
        ,, *gratiosa* (Waag.) (Diener's "*M. vihiana*").
    Spirifer (*Spiriferella*) *rajah* Salt.[2]
    Spiriferina (*Spiriferellina*) cf. *bilotensis* Reed, var. *curta* Reed (a variety found in the Middle Productus Limestone).
    Athyris (*Spirigera*) *xetra* (Dien.),
        ,, (*Cleiothyridina*) "*royssii* Lev." (many varieties, broad, long, flat and globose probably including *A.* (*C.*) *pectinifera* (Sow.) and other species)
        ,, ,, *subexpansa* Waag.
    Dielasma biplex Waag. (cf. Reed's variety *protracta*),
        ,, *acutangulum* Waag.
    Camarophoria purdoni Dav.
    Hemiptychina himalayensis Dav.

This limestone is succeeded by a sequence which still comprises shale and limestone, the latter being now subordinate. This shaly series corresponds to the bulk of the Productus Shales of Spiti and the Kumaon Himalaya, and is fossiliferous, the fossils occurring chiefly in patches which evidently represent hollows in an old sea floor. The shales are mostly of a dark colour. Three zones have been distinguished by Hayden and Middlemiss, the lowest characterised by an abundance of the form *Marginifera himalayensis*, the middle by an enormous predominance of *Spirifer rajah*[3] ; and the uppermost usually dark shale weathering white, by the preponderance of lamellibranchs associated with the ammonoid,

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[1] *Rec.*, XL, 240 (1910).
[2] F. R. Cowper Reed. *Pal. Ind.*, New Ser., Vol. XVII, 22 (1931).
[3] Probably mostly *Spirifer* (*Spiriferella*) *vercherej* (de Verneuil).

Xenaspis carbonaria (Waagen's "*Xenodiscus carbonarius*"). The faunas of the three zones are evidently closely related to one another and are combined in the following list :

Brachiopoda—

(L.) *Dielasma latouchei* Dien. ,
(L.) *Camarophoria purdoni* Dav.,
(L.) *Athyris(Cleiothyridina)* cf. *gerardi* Dien.,
(L.) ,, ,, *subexpansa* Waag.,
(L. M.) *Spirifer* (*Neospirifer*) *muaakheylensis* Dav.,
(L.) ,, (,,) *nitiensis* Dien.,
(?) ,, (,,) *warchensis* Reed, var. *scabrosa* Reed,
(L. K.) ., (*Spiriferella*) *rajah* Salt.,
(L.) *Spiriferina* (*Spiriferellina*) cf. *bilotonsis* Reed var. *curta* Reed),
(L.) ,, (,,) *zewanensis* Dien.,
(L.) ,, (*Mansuyella*) *ornata* Waag.,
(L.) *Lyttonia nobilis* Waag.,
(L. U.) *Chonetes lissarenis* Dien.,
(M.) ,, cf. *vishnu* Salt.,
(U.) ,, off. *variclata* d'Orb.,
(L.) *Productus waagenianus* Girty (a Guadalcupian species).
(L. M. U.) ,, (*Waagenoconcha*) *abichi* Waag.,
(L. M. U.) ,, *gangeticus* Dien.,
(M.) ,, aff. *cancrini* de Vern.,
(U.) ,, (*Linoproductus*) *cora* d'Orb.,
(U.) ,, (*Dictyoclosus*) *spiralis* Waag,
(L. U.) ,, *Marginifera himalayensis* Dien.,
(U.) ,, ,, cf. *helica* Ab.

Lamellibranchiata—

(U.) *Schizodus* cf. *rotundatus* Brown,
(U.) *Pleurophorus* aff. *complanatus* Waag.,
(U.) *Pseudomonotis* sp.,
(L.) ,, (*aviculomonotis*) *middlemissi* Dien.,
(U.) ,, (,,) aff. *radialis* Phill.

Cephalopoda—

(U.) *Xenaspis carbonaria* Waag.

(L., M. and U.—Lower, Middle and Upper, respectively, of the three zones).

The probabilities are that the above list should be combined with the preceding to give the complete fauna, as known, of the Productus Shales of Kashmir.[1] This fauna may be assigned with some confidence to the Upper Permian.

The succession in the Golabgarh Pass is as follows :—

(Blue-grey Triassic limestone forming the core of the syncline.)

Productus Shales (330 feet)	(C) Black shales, 10-20 feet thick, with lenticular patches of limestone containing *Spirifer rajah*, etc.
	(B) Greenish, earthy, micaceous, sandstones, 300 feet thick, with caste of fossils here and there, including a small *Marginifera*.
	(A) A thin band of black shales.
Zewan beds (430 feet)	(iii) Thin-bedded slabs of dark, foetid limestone with many beautiful plumes of *Protoretepora ampla* and amongst other fossils, *Spirigerella derbyi* var. *acutiplicata* Waag.
	(ii) A sandy and shaly stage, characterised by the brachiopods listed above and the absence of *Protoretepora*.
	(i) Soft, light-coloured, earthy sandstones which towards the top are calcareous in patches; these beds, which are about 230 feet thick, lie with perfect conformity upon, *Gangamopteris* beds.

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[1] To which may perhaps be added : *Chonetes grandicosta* Waag, *Spririfer* (*Paeckelmannella*) *niger* Waag., var. *devia* Reed, and *Entolium aviculatum* (Swallow).

No trace of the Kuling series, whether Zewan beds or Productus Shales, has been found in the country immediately northwest of Uri.[1] On the south-western or Punch side of the range, no Permian or Triassic strata are seen in association with the main exposure of the Panjal Trap, but where the latter formation is exposed as inliers in the inverted folds of Eocene limestone, three small outcrops of Permian or Triassic strata have been noted by Wadia.[2] In one of them, the *Gangamopteris* beds, the Zewan beds and the Productus Shales are all absent and the Trias rests directly and unconformably upon the traps ; in the other two (Mandi and Sangliani), the unconformity is slightly less, the *Gangamopteris* beds and the *Protoretepora* stage are missing, and some 200 feet or less of Upper Zewan and Productus Shales rest upon ash beds belonging to the Panjal Trap series. Other trifling occurrences of fossiliferous Permian shales, squeezed in between the traps and the Nummulitics, have been recorded. These representatives of the Kuling system are described as consisting of quartzites and semi-crystalline limestone interlaminated at the top with black micaceous shales. The limestone is crowded with fossils, most of which are too poorly preserved for determination, and the shales also contain a few limonite casts of lamellibranch and brachiopod shell valves ; amongst the fossils it has been possible to make out the following :— *Athyris royssii*, *Dielasma latouchei*, *Pseudomonotis griesbachi*, *P.* cf. *aurita*, numerous specimens of *Schizodus* including one comparable to *S. rotundatus*, and species of *Productus*, *Spirifer*, *Derbyia* and *Chonetes*.

In the Pailgham outcrop, exposures are poor and fossils difficult to obtain. Amongst the latter was found a specimen of *Popanoceras*, a genus characteristic of both Permian and Trias, and species of *Productus* belonging to the *semireticulatus* section.[3]

Zewan beds are evidently exposed below the junction of the Rathak and Burzil rives, on the road from Gurais to Burzil, since a slab of limestone collected by Hayden therefrom has yielded *Protoretepora ampla* and a sepecies of *Acanthocladia*.[4]

THE PRODUCTUS SHALES IN THE GREAT HIMALAYA OF GARHWAL AND KUMAON.

In the higher parts of Garhwal and Kumaon, neither the conglomerate nor the calcareous sandstone of the Spiti Permian (Kuling) has so far been recorded. The Productus Shales, however, although only from 120 to 250 feet thick, are an easily recognised horizon and provide an important landmark in the elucidation of the structure of the central Himalaya. They are described by Griesbach as overlapping in some of the sections the several stages of rocks which were supposed by him to be of Carboniferous age but which there is reason to believe are much older.[5] The unconformity at the base of the Productus Shales, although definitely recognised by Griesbach, is this way considerably greater than he supposed. The dark outcrop of these shales makes a striking contrast with the dazzling White Quartzite (Muth Quarzite) which formed the greater part of the floor on which they were deposited. The upper surface of this quartzite is described by Griesbach as being often rugged and denuded ; occasionally the bed is missing, as for instance, on the left side of the Dhauli Ganga where the Productus Shales rest immediately upon the "Red Crinoid limestone" (Silurian). Were it not for the band of Productus Shales in the White Quartzite cliffs of the Lissar valley, the section exhibited might be mistaken for an unknown sequence instead of what it represents, which is a succession of denuded isoclinal folds. At their upper limit, the Productus Shales pass up into Triassic strata and the later through Rhaetic deposits into Liassic limestones without any apparent break. The Shales are described as having suffered much from crushing and folding, having apparently played the role of lubricant for many of the thrusts.

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[1] D. N. Wadia. *Rec.*, LXV, 212 (1931).

[2] *Mem.* LI, 248-9 (1928).

[3] C. S. Middlemiss. *Rec.* XXXVII, 322 (1908). The exposure at Eishmakam in this Lidar valley, half way between Islamabad and Pailgham, belong to this *Syringothyris* Limestone and not to the Zewan formation. The sections at Kollur, Dowhat (Dahwot) and Lur (Lor) probably belong to the Agglomeratic Slate.

[4] *Pal. Ind.*, New Ser., Vol. V, Mem. 2, 101 (1915).

[5] *Mem.* XXIII, 63 (1891). They seem to have been assigned to the Carboniferous chiefly because of their position beneath the Productus Shales with their Permian fossils.

As in Spiti, the beds consist for the most part of very dark, exceedingly friable occasionally micaceous shales, here and there containing carbonised vegetable matter or coal ; a few irregular partings of hard, ferruginous sandstone, sometimes replaced by a string of nodular clay iron ore, relieve the monotony of the shales. Both shales and sandstones are fossiliferous, the best specimens being found in partings of gray sandstone which is often crowded with *Productus*.

The following fossils, most of them from the Niti area and upper Lissar valley in the old district of Johar, have been identified by Dr. Diener :

Brachiopoda—

**Athyris* (*Cleiothyridina*) "*royssii*" Lèv. (Probably including *A.* (*C.*) *pectinfera* (Sow, and *A.* (*C.*) *interposita* Reed),
,, ,, *gerardi* Dien.,
**Spirigerella derbyi* Waag. var. *acutiplicata* Waag.
Dielasma latouchei Dien.
Martinia glabra Mart .,
Spirifer (*Neospirifer*) *ravana* Dien. (Probably a variety of *S.* (*N.*) *marcoui* Waag.)
,, ,, *musakheylensis* Dav.,
,, ,, *nitiensis* Dien.,
,, ,, *fasciger* Keys.,
,, *joharensis* Dien.,
,, *bambadhurensis* Dien.,
,, (*Spiriferella*) *rajah* Salt. ,
Productus gangeticus Dien.,
,, cf. *cancrini de* Vern.,
,, (*Linoproductus*) *cancriniformis* Tschern.,
,, (*Ruthenia*) *purdoni* Dav. (Probably Reed's variety *castrensis*), Productus Limestone.
,, (*Waagenoconcha*) cf. *abichi* Waag., var. *serialis* Waag.
Marginifera himalayensis Dien.
**Chonetes vishnu* Salt.,
* ,, *lissarensis* Dien.,
,, cf, *uralica* Möll.

Lamellibranchiata—

Aviculopecten hiemalis Salt.,
Goniomya sp.
Liebea aff. *hausmanni* Goldf (Probably identical with *Aphania salinaria* (Reed) from the Lower Productus Limestone).

GastropoDa—

- *Pleurotomaria* cf. *punjabica* Waag.
- *Naticopsis* sp.
- *Bellerophon* sp.

The commonest forms are those asterisked, but the abundance is often very local.

In the eastern parts of Kumaon, in the Byans area, much restricted examples of the Productus Shale fauna have been collected. The most interesting is one from Lilinthi which has yielded very small specimens of seven genera of ammonoids.

Brachiopoda—

- *Marginifera himalayensis* Dien.,
- *Spirifer* (*Neospirifer*) *musakheylensis* Dav.
- *Athyris* (*Cleiothyridina*) *gerardi* Dien.

Cephalopoda—

- *Hyattoceras* aff. *cumminsi* White.,
- *Adrianites* (*Hoffmannia*) sp.,
- *Gastrioceras* aff. *marianum* de Vern.
- *Pericyclus* sp.,
- *Lilinthiceras* sp.,
- *Brancoceras* sp.
- *Nomismoceras smithi* Dien.

From a calcareous band in the Productus Shales above Nihal have been obtained many specimens of *Chonetes transitionis* Krot., *Nuculana* associated with *Leda* cf. *speluncaria* Gein., two species of the European Permian.[1]

From the Productus Shales in the Lebung Pass on the northeast boundary of the Almora district, Heim and Gansser collected the two rare ammonites, *Cyclolobus oldhami* Waag. and *C. walkeri* Dien.

The Productus Shales fauna, as displayed in Garhwal and Kumaon, has a peculiar character of its own and most of its determinable species are autochthonous. Nevertheless, as already remarked, it shows a relationship with the Productus Limestone of the Salt Range and appears to correspond for the most part to the Upper division of the latter.

BALUCHISTAN.

Among the Triassic shales exposed in the hills of the Zhob valley in north Baluchistan, Vredenburg reports an outcrop of slates associated with *Fusulina* limestone. The junction of these beds with the Trias is either a fault or an unconformity, but the *Fusulina* bed is presumably of Upper Carboniferous age.[2]

Beds of Carboniferous and Lower Permian age have been found by Mr. Tipper northwest of the town of Kalat, in some hills at the southern end of the Manguchar valley, and have yielded *Productus* and other fossils.[3]

REWAH STATE.

The Lower Permian marine beds of Rewah State, *i.e.*, on the Peninsular side of the Gangetic alluvium, are described later, since they are associated with beds containing Gondwana plant remains.

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[1] *Pal Ind.*, Ser. XV, Vol. I, Pt. 5, pp. 114-115 (1903).

[2] *Rec.*, XXXI, 165-166; see also map, Pl. 18 (1904).

[3] *Rec.*, XXXVIII, 201 (1909).

INFRA-TRIAS OF HAZARA.

As delimited by Middlemiss, the term Infra-Trias has been applied more or less provisionally to a series in Hazara, mostly lying with marked unconformity upon the upturned edges of the Attock Slates.[1] Between these two formations there is a great stratigraphical and physical break which, in the "Metamorphic zone" to the west of Abbottabad, is probably bridged to some extent by the Tanawal beds. To what degree the Infra-Trias is distinct from the Tanawal is not yet clear, and a considerable proportion of the Tanawal "quartzites" have been found by Wadia to be merely silicified Infra-Trias limestones, intermediate stages in silicification being common in east Mansehra.[2] In the Gandgarh range typical Infra-Trias dolomitic limestone is found along the strike of outcrops of the Tanawal quartzites, and the latter are seen to contain layers and patches of coarssely crystalline dolomite.[3] The Infra-Trias is characterised by its short lateral extent, a result due partly to want of exposures but also partly to overlap by the next higher series, the Trias. The formation, which is mainly a limestone one, is well exposed in the classic area of Sirban Hill. It has been subdivided by Middlemiss into :

(4) Upper limestones	2,000 feet
(3) Lower sandstones	150 ,,
(2) Lower shales	
(1) Basal conglomerate	50—100 ,,

The lowest stage, though of no great thickness, is of interest in that it probably represents the ubiquitous Talchir boulder bed of the Indian Gondwanas. The pebbles and boulders, composed of fragments of the underlying slates and quartzites set in a fine, purple, sandy clay or shale, are generally sub-angular ; many of them, in the Tanakki glen section of the Sirban Hill where the conglomerate is well exposed and at a village a short distance S. S. E. of Garhi Habibullah Khan, are well glaciated.[4] The fragments vary from mere pebbles to large boulders, but average in size that of a cricket-ball. Middlemiss describes the conglomerate as roughly but distinctly bedded, layers of finer and coarser material alternating with each other. The lowermost bed is much the coarsest and its higher layers pass up into the shale stage by the gradual decrease in size and number of the pebbles. In metamorphosed areas, the rock shows varying degrees of deformation and change. The first stage appears to be the development of a cleavage and the arrangement of the pebbles in their soft matrix with their long axes at a considerable angle with their bedding planes ; the pebbles when extracted show some of the matrix, originally a fine shale and now a cleaved slate, adhering to their ends, thus forming small lenses of dual rock. In the most advanced stages of deformation, the pebbles are represented by mere flakes which are so drawn out, flattened and traversed by parallel shear-planes along which metamorphism has begun, that it is difficult to trace their original boundaries.[5] Some of the more deformed conglomerates may belong to the Tanawals rather than to the Infra-Trias, supposing these two formations to have separate individuality.

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[1] *Mem.*, XXVI, 17 (1896).

[2] *Rec.*, LXV, 207 (1931).

[3] *Gen. Rep. Rec.*, LXVI, 121 (1932) ; D.N. Wadia.*Ibid* .LXVIII, 147 (1935).

[4] *Gen. Rep. Rec.* LXII, 153 (1929).

[5] C.S. Middlemiss, *Mem.* XXVI, 55 (1896).

The geographically nearest taxial equivalents to this conglomerate are the Blaini Conglomerate of the Simla area and the Salt Range Boulder Bed, both of them in all probability representatives of the Talchir stage of the Peninsular Gondwana sequence.

The shales, never more than 20-30 feet thick, are typically purple in colour, and are in places metamorphosed to an extremely fissile, schistose slate.

The shales in their turn pass up into a set of somewhat coarse sandstones, which as a rule are deep purple in colour but frequently become bleached towards the top and assume a saccharoidal aspect. The joints and bedding-planes are sometimes traversed by grey chert veins. From analogy, these sandstones should be the equivalent of the Speckled Sandstone of the Salt Range; their metamorphosed varieties are indistinguishable from beds mapped as Tanawals.

In places, the change from the sandstones into the overlying limestone is also gradual, the lowest member of the latter being a deep purple, very sandy limestone. Higher up, the limestones become less and less sandy and the colour becomes fainter and fainter attaining ultimately a white or cream colour. It is never dark grey or mottled as in the case of the Trias, and by these characters can be easily distinguished therefrom in the field; it is also more compact and better bedded. A small amount of magnesia is present. A fine cross-jointing, deeply eaten into by the weather, and seen in many cases even in the metamorphosed varieties, gives the rock a very characteristic appearance similar to that of a butcher's chopping-board. The upper beds show a vesicular tendency on a small scale, the pea-sized vesicles being filled with calcite. The uppermost layers also contain many bands of chert lying parallel to the bedding, the result probably of the metmorphosing action of the volcanic beds which succeeded them at the beginning of the Triassic period; the absence of fossils is perhaps due to the same cause. A few unimportant beds of white felspathic grit occur among the upper limestones. Marmorisation has been noted in a few cases. In the Kagan valley and the Kishenganga valley of the Himalaya-Hazara syntaxis, the Infra-Triassic limestones are seen to be interstratified sometimes with the Panjal traps and tuffs, sometimes with the Agglomeratic Slate,[1] or, perhaps more characteristically still, sandwiched between the trap and slate.[2] In this syntaxis the limestone is also found as inliers in all sufficiently denuded anticlinal flexures of the Nummulitics and Murrees. Close by, on the western side of the Indus, a massive outcrop of Infra-Triassic limestone is similarly associated with a dark green, slaty, doleritic trap, which is both interbedded with and intrusive towards the limestones.

In the Simla-Chakrata area, the Infra-Trias limestone is matched by the Lower Krol Limestone, which not only overlies a similar sequence of conglomerate and metamorposed clays and sandstones, but resembles the Hazara rock in its chopping-board mode of weathering, its fine-bedding, its semi-crystalline to exceedingly fine-grained texture, its unfossiliferous character, and the occurrences in parts of the rock of thin sheets of chert. The Infra-Trias limestone of Hazara evidently includes the equivalent of part at least of the Productus Limestone of the Salt Range and the Permian of the Himalaya. The Infra-Trias series is, in fact, made up of glacial, lacustrine, volcanic and marine deposits, representing a change from the Gondwana continental conditions to the Productus sea of the Himalaya, the Salt Range and Baghalkhand.

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[1] D.N Wadia. *Rec.*, LXV, 208 (1931).

[2] D.N Wadia. *Rec.*, LXVIII, 163 (1934).

THE "GREAT LIMESTONE" OF JAMMU, KASHMIR.

In the foot hills of the Kashmir Himalaya, occurring mainly within the two districts of Riasi and Mirpur, in the province of Jammu, a chain of large inliers of unfossiliferous, dolomitic limestone is seen extending from Purl in Punch south-eastwards to beyond Riasi, a distance of seventy miles, parallel to the prevalent strike of the outer Himalayan ranges.[1] The rock is dolomitic, the greater part of it containing as much as 18·54 per cent of MgO; one band near the top is a cement limestone with only about 1·7 per cent of magnesia. The rock of these inliers, which form prominent hog-backed hills amid the broad belt of Tertiary sediments, has been designated as the "Great Limestone". It was assigned by Lydekker on the evidence of a *Fenestella* to the Carboniferous, and its close lithological resemblance to the Infra-Trias of Hazara had also been noted. The recent discovery by Mr. Wadia of a band of the Agglomeratic Slate, interstratified with low horizons of the limestone confirms these general indications and points to an age approximating that of the Lower Permian or Upper Carboniferous.[2] The great Limestone of Jammu has achieved a vicarious celebrity by reason of the coal seams and bauxite deposits of some economic importance found in the Subathu (Eocene-OLgocene) beds immediately overlying it. A few irregular patches of these Tertiary beds have been left as a skin over the surface and in the corrugations of the limestone. The general structure of these limestone inliers is that of a comparatively open dome with subordinate folding and warping but no isoclinal compression. The southwest margin of each inlier is largely disrupted by steep strike faults of large throw; these faults which produce prominent fault scarps, tend to become reversed, but disappear towards the pitching end of the folds. The inliers are remarkably uniform in their structure as well as in their lithology.

There are three principal outcrops of the limestone. The most westerly, that of Ranjoti-Devigarh, lying to the east of Kotli, is composed really of two N.W.-S.E. outcrops echelonned on one another and mutually separated by a thin belt made up of Subathu and Murree sediments and strips of the limestone itself. The larger member of this dual inlier, with its peak of Ranjoti (6,303 feet), is some 18 miles long and about three miles broad; the smaller, with its peak and ruined fort of Devigarh (5,132 feet), lies generally to the south of the larger and is only 7½ miles long and less than 2 miles in width. This double outcrop, cut through by narrow canyons, forms the cores of two broad, not very irregular, anticlinal domes, pitching abruptly at the extremities. To the S. E. of this exposure and along its general strike is the largest of the three outcrops, situated to the north of Riasi extending from Naoshera into Jammu, interrupting the line of division between the Siwalik and Murree formations, and with a strike which is W.N.W.-E.S.E. in the western half and N.W.-S.E. in the eastern. Its general structure is that of an anticlinal flexure broken and faulted on its steep outer face and perhaps complicated with minor folds; it forms the main mass of Sangar Marg hill and, to the north of Riasi, a picturesque ridge through the centre of which the Chenab has cut a precipitous gorge. This inlier has a length of about 30 miles and a width varying from five to seven miles. The third inlier lies a few miles to the northeast of the last, well within the Murree zone, extending for about 18 miles W.N.W.-E.S.E. from the Ans valley southeastwards to the Chenab river some miles below the Ramban bend ; it also appears to occur on the line of a broken anticline, the general dip being to the northeast.[1]

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[1] D.N. Wadia. *Rec.*, LXXII, 163 (1937).

[2] D. N. Wadia. *Mem.* LI, 193 (1928) ; Gen. Rep. *Rec.*, LXIX, 61 (1935).

The base of the limestone is nowhere seen ; a considerable thickness is said to be exposed—over 1,500 feet in the Ranjoti-Devigarh inlier, according to Wadia—though reduplication by thrust-planes was suspected by R. D. Oldham.[2] All round the double outcrop of Ranjoti-Devigarh is a thin strip of Subathu beds, the continuity of which is interrupted only for short distances in two or three places ; the longest interruption is along the southwestern margin of the Devigarh outcrop, where a fault is located, and it is here that the small exposure of Agglomeratic Slate has been found.[3] In most places, the relationship between the two formations appears to be one of uniformity and parallelism. In some localities, however, as for example where the Punch river cuts its way into the attenuated neck of the limestone, the real unconformity between the two is made manifest by a violent discordance. The Riasi inlier, whose southwest flank is also a steep fault, has along its northern margin a well-defined rim of Subathu strata, carrying important deposits of anthracitic coal, iron ore and bauxite, and lying with a pronounced unconformity upon the limestone. The limestone of the third or inner inlier is succeeded by Murree sediments with the same apparent conformity, except near Shartalla where the latter beds are seen striking against the broken edges of the limestone cliff.[4]

The Great Limestone is described as a dense cryptocrystalline or non-crystalline rock, contrasting strongly in this respect with the often earthy nummulitic Subathu limestone close above it. It is hard, fine-grained, homogeneous, blue grey to cream in colour, generally thin-bedded, much jointed and irregularly fissured. Locally, it is characterised by an abundance of chert concretions and disseminated flint among its upper layers. Bands and lenses of chert and flint, up to two feet thick, also occur in these upper horizons and bear evidence of metasomatic replacement.[5] As already noted, the rock is dolomitised and sometimes approaches true dolomite, assuming a yellow colour, a greater density and increased resistance to acid. Partings of other sedimentary rocks are rare ; Simpson describes some interbedded bands of shale, usually siliceous and often flaggy, at the southeastern end of the Riasi outcrop, and Medlicott also mentions the occasional intercalation of bands of siliceous slates and flags, but in theRanjoti-Devigarh inlier Wadia failed to find any shaly or slaty partings in the rock from top to bottom. The joints and fissures in the limestone are penetrated by dykes and irregular masses of altered peridotite or serpentinised dunite of Eocene age ; veins of galena found in parts of the limestone have been mined to some extent in former times.

In its extensive silicification, its partly dolomitic character, its deeply grooved chop-marked, weathered surfaces, and its other lithological and physical features the Great Limestone shows a close resemblance to the Infra-Trias of Hazara ; petrologically, it is also said to be very similar to the Krol limestone of the Simla-Chakrata area ; in chemical constitution, according to Auden, it resembles closely the Deoban and Shali limestones. The Infra-Trias, Krol, Deoban and Shali rocks are all described in this chapter. No trace of fossils has been observed in the Great Limestone, except in the inner inlier where the impression of a *Fenestella* has been recorded. The lowest exposed horizons in the Ranjoti-Devigarh inlier have also yielded some slender rod-like bodies resembling *Fusulina*, but showing no structure under the microscope.

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[1] *Mem.* XXII, 202 (1883) ; *Ibid.* LI. 253, 322 (1928) ; *Rec.*, IX. 53, 157 (1876).

[2] *Mem.* XXXII, 195 (1904).

[3] D. N. Wadia. *Rec.* 72, Pl. 11 (1937).

[4] Lydekker considered the boundary to be a fault. See *Rec.*, IX, 157 (1876).

[5] *Gen. Rep. Rec.*, LXIX, 61 (1935) ; *Ibid.* LXXII, 167 (1927).

The interbedded band of Agglomeratic Slate is to be seen at the base of the Devigarh scarp, opposite the village of Sumlar, occurring in what appears to be a disrupted upthrown portion of the limestone. It is composed of 200 feet of black slaty, scarcely altered tuff, weathering to a light ashy grey colour. The band probably belongs to one of the lowest exposed horizons of the limestone formation. Wadia calls attention to the fact that the Agglomeratic Slate of the Pir Panjal, to the northeast, often contains intercalations of limestone, some of it fossiliferous. As we have already seen, the age of the Agglomeratic Slate varies at different localities from the Moscovian to the Artinskian ; in the main, however, it is Uralian or Upper Carboniferous.

BLAINI SERIES.

Relationships and Sub-division.—Lying mostly upon the Simla Slates or the Jaunsars, and frequently associated with the overlying Infra-Krol slates with which it is now grouped as one series, is one of the most unique and striking rock associations of the western Himalayas. It has been called the Blaini (" Blini "), after the old name of the stream—now the Baliana—flowing northwest from Solon. Although very thin, it is unusually persistent and affords an extremely useful clue to local structure. Amongst its members is a boulder bed of obviously glacial origin, which has so much resemblance to the Talchir Boulder Bed that the group was at first assigned to this series. Later it was suggested that the Blaini beds were older than the Talchir and represented a much earlier glacial period, that of the Cambrian, which has been recognised in south China, south Australia, south Africa and northern Europe. This suggestion was made on the assumption that the Purana system, which plays such a prominent part in the Peninsular area, must have representatives in the Himalaya, and that some of the unfossiliferous beds on the south side of the chain, referred somewhat arbitrarily to systems which on the north side were abundantly fossiliferous, were the equivalents of the Purana. The work of Pilgrim and West has shown, however, that there has been considerable inversion of the rocks in the Simla area, that the Jutogh and Chail series, although overlying the Blaini in many places, are probably at least as old as the Purana, and that there is nothing, therefore, against the Blaini being the equivalent of the Talchir which it so forcibly resembles. A frequent and typical sequence in this group is :—

Blaini series . . .	Infra-Krol stage .	Blaini Limestone. Upper Boulder Bed.
	Blaini-stage . .	Bleached Slates. Lower Boulder Bed.

The double boulder bed was at first thought to be a matter of reduplication by folding but, although separated from one another by no more than 200 feet and often considerably less, these two members can be traced for long distances twenty miles and more—with little variation in thickness, no sign of a closing fold, and never any repetition of the limestone below the lower bed. Near Solon, the limestone also seems to be double, but the structure is complicated by imbrication.[1] Occasionally, as near Wakna, south of Jutogh, the limestone occurs with the Bleached Slates between the two boulder beds.

From the work of Auden, there is a possibility that the Blaini group is in reality the basal portion of the Infra-Krol, and the " Bleached Slates " nothing but ordinary Infra-Krol slates in which occur the two typical rock facies of the Blaini, a boulder bed or tillite and a limestone. The boulder bed may occur alone, the limestone may occur alone, or there may be several boulder beds with or without limestones. This great variation in the detail of the sequence is a result largely of the frequent dying out laterally of the boulder beds and limestones. To what extent the recurrence of the boulder beds and the limestones is due to original sedimentary repetition, and to what extent to imbricate faulting is still uncertain but that there must have been locally more than one boulder bed is shown by the presence in some of the tillite itself of boulders of an older tillite.[2]

The thickness of the Blaini stage—as we may call it—varies considerably but the sequence is frequently incomplete and one or more of its members are seen to be missing ; the boulder bed is usually from 10 to 100 feet thick, a common thickness for the limestone is 15-20 feet (occasionally rising to 50 or 60 feet), and the belt of slates separating the boulder beds—the so-called " Bleached Slates "—may be anything up to about 250 feet. The minimum thickness of the Infra-Krol stage is in the neighbourhood of 500 feet but no precise estimate is possible. These two stages form what may be called the Blaini series and correspond more or less to the Talchir series forming the base of the Lower Gondwana.

Blaini stage.—The Blaini stage is well developed northeast of Chail, becomes somewhat attenuated when traced in the direction of Simla but thickens again in the immediate neighbourhood of that station ; in these parts the beds are never far from the horizontal. In the type area of the Baliana river, they separate the Jaunsars below from the Infra-Krols above in a normal inverted syncline, dipping towards the northeast ; a little southwest of this, four or five wisp-like outcrops are brought up by imbricate faulting among the Jaunsar beds.

The Blaini boulder bed and an associated pink limestone have been identified in the bed of the Shallu river, east of Chepal (Chaupal), to the northeast of the Chaur *massif*, where it is aparently overlain by the Jutogh carbonaceous slates. A comparatively large outcrop occurs to the east of Dadahu and at Narendranagar ; between Dadahu and the Tons river, the Blaini for many miles forms part of an unusually regular sequence involving Mandhalis, Jaunsars, Blaini, Krol and Tal beds, in the northeastern limb of two large synclines.

In interrupted ribbons and patches, the Blaini stage has been traced southeastwards across the upper Jumna into the Dehra Dun district and Tehri Garhwal, where it is displayed in a syncline involving also Krol and Tal rocks. In Tehri Garhwal it lies normally above the Nagthat or Jaunsar series. Auden finds that, east of longitude 78°7′ the Blaini stage consists of two boulder beds separated by banded bleached slates and greyish quartzites ; with the upper boulder bed is associated the pink magnesian limestone so typical of the Blaini of Simla. West of this longitude, between the Jumna and the town of Dehra Dun, the lower

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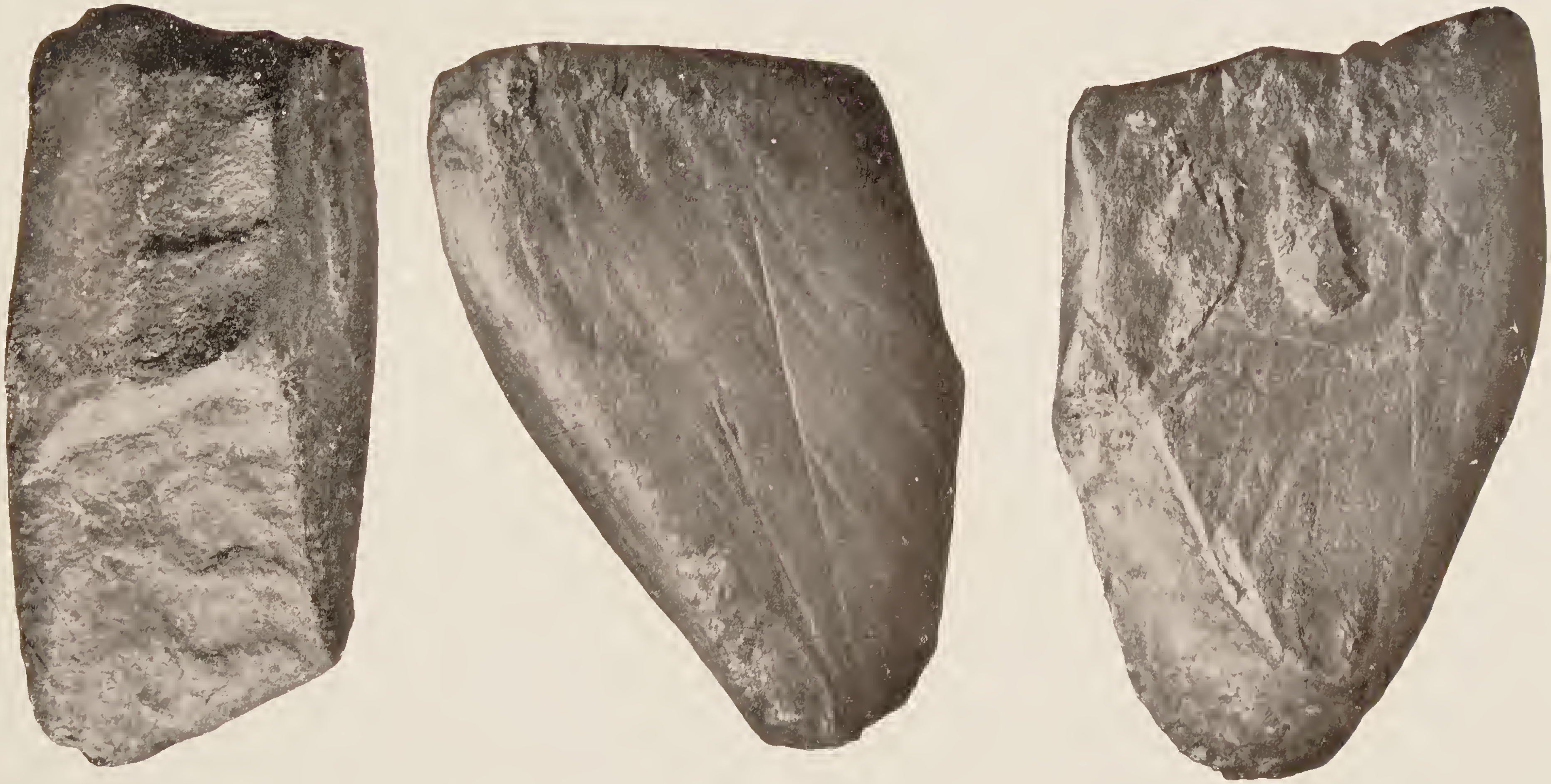
[1] *Gen. Rep. Rec.*, LXII, 168 (1929).

[2] J.B. Auden. *Rec.*, LXVII, 375 (1933).



SMOOTHED AND STRIATED BOULDER, BLAINI STAGE, SIMLA.

(Half natural size.)

Sache, photo.

G. S. I., Calcutta.

boulder bed is not seen and appears to have been overlapped by the upper boulder bed and limestone, below which there is a striking unconformity.[1]

The Blaini boulder bed and limestone are well exposed west of Lachmanjhula and at the confluence of the Huinl and Ganges rivers northwest of Kota.[2] The stage has thus been traced with small interruptions from Subathu to the Ganges, a distance of a hundred miles. Further southeast it has been followed into British Garhwal as far as the Medi Gad, five miles N. N. E. of Lansdowne, and is equivalent in part to the " Boulder bed " or "Volcanic Breccia" of Middlemiss Purple Slate series, the two having been joined up by mapping.[3]

It is very doubtful whether the Blaini stage is present in Chamba State, as claimed by McMahon.[4] As we have seen, it is believed to have a representative in Hazara, in the form of a conglomerate which shows no definite indications of a glacial origin ; the unconformity beneath this conglomerate—the Tanakki conglomerate—is much greater than that beneath the Blaini of Simla. In the eastern Himalaya, a boulder bed, possibly of glacial origin, has been recognised below Darjeeling. A definite tillite, probably of this age, has been identified in upper Sikkim (*vide infra*) ; this is interesting in that it lies on the north side of the Great Himalaya range. The boulder bed of the Salt Range forms a geographical link between the Blaini boulder bed and that of the Talchir series in the Peninsula.

Mr. R. D. Oldham's original suggestion that the so-called Blaini " conglomerate" is not ordinary conglomerate but a glacial boulder bed comparable with and probably equivalent to the Talchir boulder bed at the base of the Gondwana system has been confirmed by the discovery of undoubted ice scratches and polished surfaces upon some of the boulders in the lower boulder bed of the Simla area[5] ; similar striated boulders are also recorded from the Blaini of the Neweli valley of eastern Sirmur.[6]

The boulder beds, usually of a dark grey-brown colour, consist of angular, subangular or rounded boulders or pebbles set in a fine-grained slaty or gritty matrix. The boulders vary in number and are sometimes absent altogether, the matrix in such cases being often a hard, greenish quartzite, full of closely packed polygonal joints. Under the microscope, the matrix is seen to consist of angular fragments of quartz, quite ungraded, set in a dirty, fine-grained, quartz-clay material with laths of secondary sericite ; exceptionally, it consists of calcite or dolomite.[7] The matrix is often laminated, and the manner in which its laminae are bent under and arch over the larger included fragments is highly suggestive of a boulder dropped on to a muddy bottom and buried in later deposits of mud.[8] The matrix of the upper boulder bed is described as occasionally carbonaceous, passing down into a base of dark red slate. To what extent volcanic material enters into the composition of the boulder bed matrix is not yet decided.

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[1] *Rec.*, LXXI, 73 (1936).

[2] *Rec.*, 72, 83 (1937).

[3] *Rec.*, LXVI, 461 (1932).

[4] *Rec.*, LXIX, 76 (1935). The beds identified by R. D. Oldham in Spiti as the equivalents of the Blaini are not glacial and are younger than the Talchirs (*Mem.*, LIII, 134, (1928). There is little doubt, on the other hand, that the Tanakki conglomerate or boulder bed in Hazara (already described), is the equivalent of the latter (*Rec.*, LXV, 127 (1931).

[5] *Rec.*, XXXVII, 129 (1908).

[6] Cyril. S. Fox. *Mem.* LVII, 38 (1931)

[7] J. B. Auden. *Rec.*, LXVII, 377 (1933);

[8] *Rec.*, XX, 156 (1887).

The boulders range in size from small pebbles up to masses of ten cubic feet and consist of dark slate (abundant and universal), greenish quartzitic grit, recrysallised mosaic quartzite, sericite-quartzite, fine-grained arkosic sanstone with a glauconite-like mineral, sandstone containing many grains of phyllite and carbonaceous slate, grit with an isotropic clay-paste matrix (a rock matched in the Blaini beds themselves at Gadhasar), green slit-stone or slate, banded slate, and vein-quartz, all of which might well have been derived from the Simla Slates, the Jaunsars and probably also the Jutoghs. Occasionally, there are fragments of a buff-weathering, microcryastalline limestone of uncertain provenance, except in one case where it appears to be of Blaini type. The boulders, the majority of which consist of slate, are usually sub-angular or angular, but well-rounded pebbles are at the same time quite frequent; the angularity is determined for the most part by the jointing and bedding thickness of the parent rock. Auden records a gradation from tillite to conglomerate containing rounded pebbles of vein-quartz.

When both are present, the two boulder beds are mutually separated by about 150-200 feet of thin-bedded shales or slates which are black when freshly exposed to considerable depths, but which show a peculiar cream-coloured tint on weathered surfaces, and were, for this reason, called by R. D. Oldham the "Bleached Slates"; this feature is not entirely restricted to this horizon but is universal and extremely typical of it. Oldham remarks on the extraordinary resemblance of the Bleached Slates to the *Gangamopteris* beds of Kashmir[1], and the two formations cannot, in fact, be very different in age.

The limestone, which occurs typically above the upper boulder bed, is hard, siliceous, microcrystalline and generally pink or cream in colour; analyses show a content of nearly 33 per cent $MgCO_3$, and sometimes over 7 per cent of silica. Its bedding is from half-an-inch to 6 inches across and is generally contorted. Auden records a less usual type of the limestone which is sandy, soft and often ferruginous, weathering to thick, dark orange brown crusts. By addition of clayey matter the limestone sometimes grades into calcareous shales and slates which may be purple or pink in colour; in places as for example at Barog railway station, these are the sole representatives of the Blaini.

In places, the boulder beds are strongly sheared, the matrix becoming cleaved, phyllitised and eventually schistose, and the pebbles flattened out and difficult to distinguish. On the northwest side of the Chaur *massif*, for instance, the Blaini when traced to the northeast becomes schistose and almost unrecognisable, the dense limestone undergoes little change but unfortunately dies out, the "Bleached Slates" take on a prominent cleavage markedly oblique to the bedding, and the boulders become crushed and flattened.[2] To the south and southeast of the Chaur also, *i.e.*, in the southeastern portion of Sirmur State, metamorphism increases not only in the Blaini but also in other beds, the boulder bed becoming altered to a phyllite in which it is difficult to distinguish pebbles from matrix such changes are best seen on the Juin-Chandpur ridge.[3] An interesting feature in these crushed and sheared boulder beds is the elongation of many of the pebbles into ellipsoids with the major axes orientated, not invariably parallel to the Himalayan trend, but occasionally in a direction more or less at right angles and parallel to the older Aravalli chain, *i.e.*, N.E.-S.W. or E N E.-W.S.W.

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[1] *Rec.*, XX, 145 (1887); *Ibid.* XXXVII, 130 (1908); *Ibid.* XLIII, 139 (1913).

[2] W. D. West. *Rec.*, LXII, 165 (1929);

[3] *Gen. Rep. Rec.*, LXVI, 125 (1932); Ibid. LXVII, 375-376 (1933).

The thickness of the whole Blaini stage is normally about 200 feet, but is often considerably less or more, as already noted. In the Ganges river just below Lachmanjhula, for instance, the thickness of the upper boulder bed and Blaini limestone alone is about 460 feet, while at Narendranagar, the former, without the limestone, is probably 1,200 feet thick. In the country around Dehra, the Bleached Slates intervening between the two boulder beds amount to some 700 feet. If like the Talchirs of the Peninsula, the Blaini group were deposited upon an uneven floor, variation in thickness would be inevitable. In spite of this, the Blainis, like the Talchirs, are extraordinarily widespread and constant in character, a result, no doubt, of their peculiar origin. The Bleached Slates and perhaps some of the Infra-Krols, would appear to take the place of the Gondwana plant beds which are found in Kashmir to the west and in the Darjeeling district to the east.

Blaini stage in Sikkim.—Of great interest is the discovery in Sikkim, first by L. R. Wager, and again by J. B. Auden and G. B. Gourlay, of pebble and boulder beds which have been recognised by Auden as the Blaini tillite. The locality is the west side of Lachi hill, north of the main Himalayan range, and the tillite is associated in a complex way with quartzites, limestones and hardened shales from which Wager collected Lower Permian brachiopods.[1] The pebbles collected by this observer are composed of quartzite, some of it rich in detrital tourmaline, pink limestone, sericite tuff of rhoylite and muscovite-granite. In the bed recorded by Auden and Gourlay, pebbles are rare and the matrix, which shows a striking resemblance to the green silty sandstones of the Peninsular Talchir stage, is a dull greenish brown grit, made up of angular and completely ungraded grains of quartz, with subordinate microcline and sodic plagioclase set in a very fine brown paste full of sericite, biotite and quartz; according to Auden this rock might be either glacial or pyroclastic in origin. On the Indian side of the main range, Fox notes a boulder bed, possibly of glacial origin, just above Tindharia station on the Darjeeling railway. In the neighbourhood and along the Tista valley occur outcrops of the intrusive mica peridotites and lamprophyres which form such a characteristic feature of the Damodar valley coalfields.

Infra-Krol-stage.—The Infra-Krol is a term given by Medlicott to certain slates and sandstones lying below the Krol Limestone of the Simla area.[2] The true stratigraphical position of these beds has been proved by Auden to be between the underlying Blainis, and the overlying Krol series which succeeds without at any rate any angular discordance. The incompetence of the Infra-Krol rocks has caused such close folding and inter faulting that no representative section is known and no reliable estimate of their thickness is possible. The fresh rocks, moreover, differ so markedly from the weathered that it is difficult to accept their identity without careful mapping.

The Infra-Krol rocks are described by Auden as composed chiefly of dark shales and slates, interbedded in a varve-like manner with thin buff-weathering bands of impure slaty quartzite from ¼ to four inches in thickness. Auden suggests that much of the Blaini and Infra-Krol may represent varved sediments associated with the Blaini glacial beds.[3] Occasionally, thicker beds of pepper-coloured quartzite are to be seen. Towards the top, below the Krol sandstone and limestones, as for instance, on the spurs south of Krol hill and north-west of Rajgarh hill, the thin bands of slaty quartzite are missing and the shales or slates are carbonaceous.

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[1] *Rec.*, LXIX, 151 (1935).

[2] *Mem.* III, Pt. 2, 17, 29 (1864).

[3] *Rec.* LXV, 132 (1931).

The banded facies weathers on the hill-sides to a very characteristic association of thin, bulbous, shiny, gritty clay-slate, often green in colour, and concentric ring-bleached slates; the latter, which are lithologically the same as the "Bleached Slates" of the Blaini, are seamed with ramifying irregular joints, which become marked out by harder ridges as a result of the liberation of iron and its precipitation as a ferric hydroxide cement.[1] On account of intense small-scale folding and the recent age of the cementation, the two rock types mentioned above usually occur together in complete chaos. Another universal feature in these rocks is the seepages of ferric hydroxide and white incrustations of ferric sulphate and chloride, derived probably from the decompositon of pyrite and covering exposed surfaces.

There is great variation in the extent of the metamorphism. The shales, for instance, which predominate around Solon, become true slates in the lower Baliana river, with a cleavage dipping to the northeast. Further southeast, they change to pearly phyllites and even become schistose ; in these places the rocks are seamed with ramifying quartz veins. Pyrite is abundant in the cleaved slates, and in all the rocks there is a large proportion of carbonaceous dirt. The bands of slaty quartzite or gritty clay-slate are often calcareous ; the tougher of these bands resemble the sandy limestone or calcareous sandstone facies of the Blaini.

The minimum thickness of the stage is in the neighbourhood of 500 feet but no precise estimate is possible. The Infra-Krols may be recognised by their stratigraphical position and by their ring-bleached slates. They evidently correspond in age to part of the Agglomeratic Slate, or to part of the Kashmir plant beds, and are to be correlated with part of Middlemiss, "Purple Slates" in Garhwal. Whether they correspond in any way to the younger horizons of the Tanawal group, or have any identity with lower parts of the Infra-Trias, future investigation will decide.

The Infra-Krols have been followed through the Dehra Dun district as far as Lansdowne in British Garhwal, where they occur as banded carbonaceous slates with saline efflorescences[2].

KROL SERIES.

Distribution and classification.—The name Krol was given by Medlicott to a limestone and quartzitic sandstone in the Himalaya just below Simla, and is derived from the Krol hill near Solon. Broadly speaking, the Krol belt of this area, as worked out by Mr. Auden, in structure, is a *nappe* made up of two inverted synclines of Krol rocks, the whole included between two thrust-planes, the Krol Thrust below and the relatively local Giri Thrust above. Followed southeastwards, the upper of the two synclines becomes much chopped up by smaller thrusts. Towards Dadahu, this upper syncline becomes less and less recognisable, but its place is taken by a much larger and more open syncline involving Tal (? Jurassic or Cretaceous) as well as Krol strata ; this large syncline is tectonically above the Giri Thrust and is thus echelonned as it were on the other two synclines. It is below the Giri Thrust that the greatest havoc has been caused amongst the yielding Krol sediments, over which the hard Jaunsars and Simla Slates have been pushed. The irregular nature of the folding of the Krol and Infra-Krol rocks is due to their incompetent character, a feature which has localised and magnified the effects of earth movement. Normally, the series follows the Infra-Krol stage of the

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[1] J. B. Auden. *Rec.*, LXVII, 378 (1933).

[2] J. B. Auden. *Rec.*, LXVII, 427 (1933).

Blaini, and is overlain by the Tals. The following sequence, most of it of shallow-water, epicontinental origin, has been established by Auden :—

	Solon area.			Tons river area.
Krol series.	Upper Krol Limestone .	Krol E. Krol D. Krol C.	Krol series	Upper Krol Limestone.
	Red Shales (Krol B).			Red Shales.
	Lower Krol Limestone (Krol A)			Lower Krol Limestone.
	Krol Sandstone (local).			

The Krol series, since it follows in a normal manner the Upper Carboniferous Blaini series, would appear to represent the Permian and probably also the Trias. The Blaini series and Krol series would thus correspond to the Lower Gondwana. Beyond the Sutlej, the Krol limestones are apparently absent and do not reappear till Kashmir is reached, where they are probably represented by parts of the Tanawal Infra-Trias or Panjal Volcanic formations. The Lower Krol Limestone, especially has many features in common with the Infra-Trias Limestones, whose place is, in some places taken, as we have seen, by the Panjal Trap. For consistency's sake, the boundary between the Permian and Trias may be assumed to be that between the Krol Red Shales and the Upper Krol Limestone ; in the absence of organic remains this suggestion is, of course, purely arbitrary. The dolerite intrusives in the Krol as well as the Jaunsar and Tal beds are probably of Dras or Deccan Trap age, and will be referred to in a later chapter.

Krol Sandstone.—The Krol Sandstone is in reality a local phase of the Infra-Krol formation, and is well exposed along the Kalka-Simla motor road, at the foot of Pachmunda hill to the west of Solon, and at Salogra. Around Solon, it can be seen passing down into the Infra-Krol through a passage zone of about 100 feet. It takes part in the Krol and Pachmunda synclines and in the synclinal structures to the southeast. On the southern face of Krol hill, it is 350 feet thick, but decreases in thickness when traced to the southeast, and dies out near Dadahu, its place apparently being taken by the upper layers of the Infra-Krol. The Krol Sandstone, or where this is absent, the Infra-Krol beds, pass up into the Lower Krol Limestone (Krol A). The stratigraphical position of the Krol Sandstone is probably comparable with that of the Infra-Trias sandstones of Hazara.

As generally seen, the lowest member of the Krol succession is a soft, crumbling iron-stained sandstone with no good bedding near Kandaghat and in the stream flowing from Solon to the Giri river, it is a hard, well-bedded quartzite. In the tight Kawal Khal syncline, it is a horny quartzite strongly veined with quartz. A conspicuous feature in this somewhat artificial stage, according to Auden, is the presence of bands of small disc-like fragments of black shale which readily bleach and are almost certainly the result of penecontemporaneous erosion of underlying Infra-Krol beds.[1] Towards the southeast, the sandstone becomes split up by bands of carbonaceous shale which disappear further in the same direction, the quartzites with shale-discs being here accompanied by coarser lenticular pebble beds. Under the microscope, Auden has found the grains in the very fine varieties of the sandstone to be all angular ; in the coarser types well rounded grains are to be seen, a result almost certainly of wind action, though followed possibly by water deposition.

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[1] *Rec.* LXVII, 379 (1933).

Lower Krol Limestone.—The Lower Krol Limestone (Krol A) around Solon is made up of rapid alternations of shaly limestone and a calcareous shale or slate, in beds from one to four inches thick. These alternations are either parallel layers or consists of lenticular pillows of limestone surrounded by calcareous shale. Near Solon, the stage is capped by 20-50 feet of a more massive limestone which is frequently dolomitic. Small-scale current-bedding is frequently seen and in a few places ripple marks with a WNW.—ESE. strike. Cleavage is universal and the calcareous shales are disintegrated into pencils and needles which lie about on the hill-sides. Eastwards, true oblique cleavage has been developed and between Dadahu and the Tons river banded grey and green slates make their appearance, in places becoming puckered, veined with quartz, and almost phyllitic. Black chert is common in thin bands or in small pillows, and a small lenticle of gypsum and subordinate anhydrite occurring at one place in the limestone is thought by Auden to be an original deposit therein. The real thickness of the stage varies from about 300 feet on Pachmunda hill to 700 feet, a few miles southeast of Solon, but the actual thickness is often reduced or multiplied by thrust-faulting. To the southeast of the Simla region, the stage becomes much thinner but is again seen well developed south of Mussoorie and along the Ganges by Lachmanjhula.

Red Shales.—Krol B consists of soft, thinly-laminated, purple-red shales with blotches and intercalations of green chloritic shale, and thin honeycomb weathering dolomitic and cherty limestones, resembling the *rauchwacke* of the Alps, the maximum thickness of the stage reaching about 300 feet. Ripple marking is sometimes seen, and near the top are parallel-bedded, shaly limestones similar to those in the Lower Krol Limestone. The shales of this stage are very incompetent and the bedding consequently is seldom preserved. Slaty cleavage is never developed.

Upper Krol Limestone.—Krol C, the most conspicuous limestone on the hills around Solon where it occurs in a single cliff from 150 to 300 feet high, is a massive dark blue, frequently dolomitised crystalline limestone, with a foetid odour on fracture, and weathering to black " chopping-board " surfaces.

Sub-stage D comprises alternations of cherty, foetid limestone in beds from ten to thirty feet thick, and black, red, green and orange shales. Its minimum thickness is about 600 feet and shale usually predominates. The chert is pale in colour and occurs as thin wisps or bands up to two inches thick in the limestones. The darker varieties of the shales often bleach like those of the Infra-Krols. Conglomerates with pebbles of vein quartz and chert are rare, but some of the limestones show penecontemporaneous brecciation. In several localities, gypsum in pockets has been noted as replacing the limestone. Soft white sandstones are often found.

The rocks of the highest sub-stage, Krol E, are well bedded, with beds from one foot to five feet thick, and afford rugged scenery. They attain a minimum thickness of about 500 feet and are seldom seen below an altitude of 4,000 feet. The main type is described as a banded grey and cream-white microcrystalline limestone, with thin crinkled veins of calcite which stand out slightly from the weathered surface in the form of sutures. Fresh surfaces of the paler varieties are white and porcellainous. With increase of quartz-grain, the limestones pass to pale sandy limestones from the weathered surface of which the quartz grains project like millet seeds, and finally to pale calcareous sandstones. The sand grains are both angular and rounded and pellets of calcareous mud are common. Less frequent are saccharoidal limestones and cream-white varieties showing tubular and ellipsoidal growths of calcite radial to cores of calcareous mud and deceptively like coral. Locally, tourmaline is a common detrital mineral in the Krol E limestones.

A highly dolomitic character is typical of most of the Upper Krol limestones some of them approaching theoretical dolomite in composition ; one of these dolomitic limestones, a little south of Top Tibba on the Mussoorie-Tehri mule-path, is beautifully ripple-marked.

North west of the Simla area, cherty limestones and interbedded red and black shales of Krol D type have been noted by Auden on the path between Bilaspur and Parnali.

Krol succession in Dehra Dun and Garhwal.—Auden has traced the Blaini Infra-Krol : Krol : Tal sequence southeastwards into Dehra Dun and Tehri Garhwal where it is exposed in the usual synclinal arrangement, with a NW.-SE. trend the following succession can be recognised :—

Upper Krol Red dolomites, limestones	3,000 feet
Krol Red Shales Lower Krol limestones and shales	1,000 „

The Krol *nappé*, which here involves not only the Krol series but the Blaini, Nagthat and Chandpur beds below, as well as the Tals above, is made up of an uninverted stratigraphical sequence of something like 20,000 feet of strata. It is bounded below by Krol Thrust, which has brought the rocks over a foundation mostly of Simla Slates but sometimes including beds as young as the Nummulitic, "windows" of which have been exposed by denudation. The upper boundary is the Garhwal Thrust which brought other *nappés* over the Krol. The Krol and Tal outcrops of the Mussoorie syncline stretch from Mussoorie southeastwards to the Huinl river in Tehri Garhwal, where they terminate. South of it and *en echelon* with it is the larger Garhwal syncline, which includes Krol rocks and is still tectonically above the Krol Thrust, forming part of the Krol *nappé* ; the Krol outcrop of this syncline ends southeastwards at Narendranagar[1]. In Dehra Dun and Tehri Garhwal, most of the Krol limestones are almost pure dolomites. The well known Mussoorie ridge, from Banog to the Landour bazar, is made up of the Upper Krol limestone, the " E " sub-stage being well exposed opposite " Stiffles cocktail bar".

The various stages of the Krol, as well as the Infra-Krol, have been traced to near Lansdowne in British Garhwal. Here the thin-bedded Krol A limestone of the Solon area, a hundred and twenty miles distant, is represented largely by calcareous slates, which were included by Middlemiss in his "Purple Slate series";[2] this change is one of original composition and not of differential metamorphism. On the "C" sub-stage (Middlemiss "Massive Limestone"), rest the Lower Tal beds, sub-stages "D" and "E" being apparently absent. Below it is stage "B" with its sheared red slates and blotches of limestone.

Since the limestones at Naini Tal in the Almora district further to the southeast are in all probability Krol, the total length of the outcrop of the series must be at least two hundred miles. Auden suggests that some limestones just north of

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[1] *Gen. Rep. Rec.* LXVIII, 68 (1934) ; *Ibid.* 71, 74, Pl. 35 (1936) ; *Ibid.* 72, 83 (1937).

[2] J. B. Auden. *Rec.* LXVII, 428 (1933).

Udaipur Garhi in Nepal may belong to this series, and it is not unlikely that the Baxa series of Bhutan, still further to the east, as well as the limestone of Mount Everest, also corresponds to the Krol (*vide infra*).

SHALI SERIES OF THE SIMLA AREA.

Opposite to the Mashobra ridge, towards the northeast, is the prominent peak of Shali (9,408 feet), forming part of a hill well known to frequenters of Simla, and consisting of a thick massive limestone. Below the main outcrop but separated therefrom by a broad belt of the so-called "Madhan Slates" is another irregularly shaped band, part of it forming the bed of the Senj (Sainj) or Nauti river. The Madhan outcrop wraps round the eastern half of this band, but the western half is bounded on the south and southwest by a narrow belt of grey slates, described as younger in appearance than either the Jaunsar or the Chail slates and dipping conformably under the Shali limestone which here forms the steep and often precipitous northern side of the Nauti Khad.[1] Pilgrim and West record a gradual transition from these grey slates, through slates which contain thin bands or lenticles of limestone, often impure, up into typical Shali limestone with its black chert bands. The limestone and slates, with some quartzites at the top and bottom have therefore been grouped together as the Shali series which undoubtedly underlies the Madhans.

The detailed structure of this area has recently been worked out by Dr. W. D. West, and will be further referred to. The Shali series, the Madhan Slates, and some still younger beds of Tertiary age (Subathu and Dagshai) have been exposed beneath a tectonic window produced by the denudation of the ancient Chail rocks which had been thrust south westwards for many miles over them.[2] The plane along which the older rocks have moved—the Shali Thrust-plane—is probably the same as the Giri Thrust, already mentioned in this chapter. Of the rocks laid bare beneath the window, those of the Shali series have features in common with the Krol and are provisionally correlated therewith. A large patch of these rocks around and including the Shali peak has been exposed and is seen to be folded in the form of a dome-structure on the eastern end of an anticline. The Shali series has been sub-divided by West as follows :—

(Madhan Slates).

Shali series . . {
- Upper or Shali Quartzite.
- Upper Shali Limestone.
- Shali Slates.
- Lower Shali Limestone.
- Khaira Quartzites.

Omitting the uppermost quartzite, the sequence shows a distinct resemblance to that of the Krol, the nearest exposure of which lies about fifteen miles to the south.

Above the white and purple Khaira Quartzites comes the Lower Shali Limestone. The lower part of this stage is a pink calcitic limestone, banded at the base ; the higher part is a massive, grey, dolomitic rock with occasional bands of chert. The Shali Slates stage includes a variety of slates and slaty limestones ; it is made up typically of dull black, splintery slates, bleaching to a light grey colour, and passing down into a banded slaty limestone and up into thin-bedded earthy limestones.

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[1] Guy E. Pilgrim and W. D. West. *Mem.* LIII, 123-124 (1928).

[2] *Rec.* 74, 133-163 (1939).

Unlike the Chail slates, those of the Shali series are neither schistose nor phyllitic, but either simple clay slates with little or no metamorphism, or true slates with a cleavage but no signs of further alteration.

The Upper Shali Limestone is an intensely hard, massive, grey or blue, dolomitic limestone, weathering to a dirty white colour, and characterised throughout almost its entire thickness by parallel sheets of black chert ; the latter are mostly from ½-inch to two-inches thick, but bands of three or four inches are not infrequent, and some are even thicker. The chert is absent from the highest beds, which consist of thin-bedded cream-coloured limestone associated with a few bands of thin-bedded quartzitic sandstone. Assuming that there is no reduplications through folding in the main outcrop, the thickness of the limestone cannot be less than 1,200 feet. It forms the summit of the Shali peak and of the range on either side. The uppermost quartzite (Shali Quartzite) is pure white in colour and sometimes contains chert.

Five or six outliers of the Shali Limestone are seen lying within the boundaries of the Madhan outcrop. In some places, slices of the Shali Limestones are described by West as having been torn off the main outcrop and dragged along by the Shali Thrust so as to lie upon the autochthonous Tertiary rocks. Other outcrops represent large fragments of the limestone which have become thrust into or caught up by the over-riding Chail rocks. The Madhan Slates appear to be post-Krol and may belong to the Trias or Jurassic. The Shali Limestone is described as differing lithologically from either the Krol or the Deoban.

THE DEOBAN LIMESTONE AND THE MANDHALI SERIES.

Here may be considered two Himalayan formations which are of doubtful age but which may possibly occupy some portion of the stratigraphical sequence described in this chapter ; they are the Deoban Limestone and the Mandhali series.

Deoban Limestone.—Above the Simla Slates of Chakrata and their accompaniments, and occupying the higher parts of the mountains north of that hill-station, is a thick limestone formation named after the Deoban peak and with a general dip towards the northeast. To the southwest, it overlies the beds known as the Mandhalis with a marked discordance which probably coincides with a thrust. It is succeeded above by a conglomeratic sequence of the same Mandhali series, among which are pebbles of a limestone which was correlated by R. D. Oldham with the Deoban.[1] If this correlation be correct, the Deoban Limestone would appear to occur stratigraphically below the Mandhalis. On the other hand, it has been suggested that the Deoban is an expanded development of the Kakarhatti Limestone and thus part of the Simla Slate series.[2] From the Kakarhatti Limestone it differs somewhat in lithological character and in its great thickness ; with the Shali Limestone it has even less lithological similarity.

The Deoban is a great limestone formation, with a varying proportion of interbedded thin shale or slate bands which are occasionally more highly coloured. The limestones are pale bluish grey, bedded, often dolomitic and sometimes oolite. Some of the beds contain chert nodules in large numbers. In others, which are generally mephitic, a peculiar pisolitic structure is developed, consisting of black nodules lying in a white matrix. Curious stromatoporoidal structures have been observed in some of the bands, and have been recorded from limestones west and south of the Giri in Sirmur, in Kumaon, in Kulu, as well as in the Slate series of the Gandgarh range of Hazara.

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[1] *Rec.* XVI, 196 (1883).

[2] J. B. Auden. *Rec.* LXVII, 365 (1933).

The Naldera Limestone occurring presumably at the base of the Chail, and the Kakarhatti Limestone in the Simla Slates are both characterised by pseudo-organic structures,[1] but these are said to be of a different kind from those found in the Deoban. The Deoban Limestone has resemblances not only to rocks from localities mentioned, but also to some of the Cuddapah beds of the Peninsula.[2]

East of the Chaur area, the Deoban formation is of great thickness, consisting mainly of massive limestones, commonly full of chert, with some inbedded shales, but with no trace of identifiable organic remains[3]. Here it has a gentle dip to the north or northwest, and shows no sign of folding till near the Tons river. It occupies the hill of Isu Tibba and extends in a wide belt to the northeast. It has been traced by Middlemiss into Tehri Garhwal, where it is associated with sombre-tinted grey shaly slate, slightly schistose in character[4]. In British Garhwal, what is believed to be the Deoban Limestone has been noted by Auden between Manwa Devi and Ganpurgarh, where it is overlain by an acid volcanic suite ; here it has been mineralised, and in it are situated the copper mines of Dhanpur-Dobri. Along the Alaknanda, this massive limestone, dipping northwards, appears to be overlain by massive quartzites and phyllites which have a resemblance to the more arenaceous type of Jaunsars near Chakrata but which are probably nearer in age to the Mesozoic Tal series ; above the quartzites and phyllites comes a suite of basic lavas very like the Panjal traps.[5] In the Gohna area, a hundred and thirty miles north of Naini Tal, occurs an irregularly crumpled succession of carbonaceous shale and dolomite. These dolomitic limestones and dolomites are grey or cream-coloured, sometimes massive, sometimes well banded, and in them have been found stromatoporoidal structures similar to those characteristic of the Deoban Limestone and its possible equivalents. In Naini Tal itself, the massive dolomites associated with the so-called "Purple Shale series" is thought to belong to the same formation as those of the Gohna area[6].

Mandhali Series.—The Mandhali, a formation founded by R. D. Oldham, shares with the Chandpur series as well as with the Nagthat or Jaunsar series the protean character which is one of its marked features. The Mandhalis comprise quartzites, slates, limestones, conglomerates and boulder beds in the most variable proportions, and interstratified in the most extraordinary manner. Slates or even limestones, for instance, are not uncommonly seen interbedded with coarse grits or conglomerates. Oldham attributes this variability to deposition in close proximity to land, a large proportion of the debris having been derived evidently from older rocks of an adjacent upland or mountain terrain. Auden suggests that the conditions of accumulation were in the main fluviatile and continental.[7] In northern Jaunsar and Bawar, where the series rests upon the Deoban Limestone, fragments of the latter, according to Oldham, are extremely abundant in the

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[1] *Gen. Rep. Rec.* XXVII, 58 (1894).

[2] D. N. Wadia. *Mem.* LI, pt. 1., 65 (1926).

[3] *Gen. Rep. Rec.* LXII, 166 (1929).

[4] *Rec.* XX, 31-32 (1887).

[5] *Rec.* LXIX, 134 (1935).

[6] *Rec.* XXIII, 24-38 (1890) ; *Ibid.* XXVII, 57-58 (1894).

[7] *Rec.* LXIX, 159 (1935).

Mandhali conglomerates, several of which are composed exclusively of rounded boulders of Deoban limestone embedded in a matrix of the same rock finely comminuted ; in southern Jaunsar, where it rests on quartzites, the series, consists almost entirely of coarse quartzites and grits.

Among the most conspicuous features of the Mandhali are the boulder beds which in places are indistinguishable from those of the Blaini series correlated with the Upper Carboniferous Talchir. The chief differences between the Mandhalis and the Blainis are (i) the disorder that prevails among the Mandhali rocks as compared with the orderly sequence in the Blainis ; (ii) the totally different sequence which overlies each of the two formations ; and (iii) the invariable presence among the boulders of the Mandhali boulder beds of limestone or marble, which is rare in the Blaini boulders. These differences, however, are not inexplicable on the assumption that the Mandhali and Blaini are equivalent. The greater disorder in the Mandhalis may be a local characteristic due to greater disturbance ; the beds succeeding them are now believed to have been thrust into their present position ; finally, the presence of limestone boulders in the Mandhalis may very likely be due to the immediate proximity and subjacency of the Deoban Limestone. Dr. West is inclined to equate the Mandhali and Blaini, and remarks that the highest stage of the Mandhali in the type area is a thin-bedded pink limestone, weathering to a cream colour, exactly like a Blaini Limestone. In this area also there is no suggestion of either a thrust or an unconformity between the Mandhalis and the underlying Deoban, but strong evidence that the latter passes up gradually into the former. On this evidence, the Deoban Limestone would occupy a stratigraphical position corresponding to the Middle and perhaps also Lower Carboniferous, and thus fill to some extent the gap between the Jaunsars and the Blaini.

South and southeast of the type area, conditions are more confused. While the Blainis pass up into the Infra-Krol : Krol : Tal succession (Permian to Jurassic or Cretaceous), rocks equated by Oldham with the Mandhalis appeared in one locality to pass up normally into the overlying Chandpurs, and it was thought possible that the Mandhali boulder beds, which graded in places into ordinary conglomerates, were not necessarily glacial but might be the agglomeratic forerunners of the tuffs in the seemingly succeeding Chandpur series. To the south of Chakrata, as well as to the east of Dehra Dun, an abrupt contrast in metamorhpism was observed between the less altered Mandhalis and the more altered overlying Chandpurs. Such an abrupt vertical change is a feature of thrust-faulting and it seemed possible that the two series might be separated from each other by thrust, distinct from that which has brought both of them over the Tal (Mesozoic) beds. The difficulty here is that the unconformably overlying Nagthat(?Devonian) beds appear to overlap the Chandpur-Mandhali boundary, from which it would follow that the presumed thrust between the Mandhalis and Chandpurs must have been pre-Nagthat and, therefore, very much older than the Tertiary thrust which brought both series up over the Tals[1]. In these particular areas, there is more incentive to correlate the Deoban and Mandhali with the upper part of the Krol (Mesozoic), but it is not definitely certain that the beds here identified as Mandhalis by Oldham and accepted as such by Auden belong really to that formation. Oldham was strongly in favour of equating the Deoban with the Krol.

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[1] *Gen. Rep. Rec.* LXXI, 75 (1936).

The so-called Mandhalis outside the type area include a boulder bed, the matrix of which is either slate, gritty slate or pure sandstone, while the boulders and pebbles consist typically of limestone or marble, dark slate, sheared quartzite and vein quartz. The rock includes slivers of limestone, which have evidently been formed *in situ* since they are too elongated to be the result of stress upon limestone fragments, and lenticles of sandstone some of which grade insensibly into the matrix. At least two bands of limestone form part of this succession, one of them closely resembling that of the Lower Krol but differing therefrom in its more frequent interbanding with slate, its markedly angular folds and its frequently sandy basis. The basal beds of these doubtful Mandhalis consist of quartzites and bleached slates, the latter reminiscent of similarly affected slates in the Blain series.

EXOTIC BLOCKS IN GARHWAL, KUMAON AND NGARI KHORSUM (HUNDES).

Among the exotic blocks found in large numbers on the Great Himalaya of Malla Johar and Ngari Khorsum, in the neighbourhood of the Chitichun (Chirchun) peaks and the Balchdhura heights, some consist of limestone identified, in a few cases, from fossil evidence von Krafft Nos. 9, 11, 12, 13, 15, 18 and perhaps 19, as well as Chitichun peak No. 1, belong to this category. These blocks are probably of the nature of *klippen*, isolated from their parent masses by extensive thrusting. The *wurzelregion* of these tectonic outliers is presumed to lie in the unsurveyed tracts to the north, northeast or east.[1]

These exotic blocks are found sometimes overlying the Spiti Shales of Jurassic-Cretaceous age, sometimes younger Flysch formation of sandstone and shale (probably Cretaceous), but are inextricably mixed with the embedded masses of andesite and other basic igneous rocks. These innumerable foreign blocks of sedimentary rock vary in size from mere pebbles to masses large enough to form features in the landscape. Blocks of limestone, sandstone, Spiti shale and Flysch representing stratigraphical horizons from the Permian to uppermost Cretaceous lie scattered in confused jumble amid the volcanics; most of the blocks are unfossiliferous or poor in fossils. Their peculiar position and their origin will be considered in the final chapter.

Lithologically, the rock of the Permian *klippen* is a light grey and red, massive, marble-like, crinoidal limestone with many cleavage planes. On blocks of this age "No. 9" and Chitichun peak No. 1 are the only two which exceed 50 feet in diameter.

It is difficult to say whether the famous crag of Chitichun No. 1 (17,740 feet), rests at all on the Spiti Shales which crop out extensively in the neighbourhood, or entirely on basic igneous rocks and their tufa, since the base of the crag is obscured by talus and the Shales and igneous rocks are intimately mixed together. The latter is described by Diener as intrusive into both the Spiti Shales and the exotic limestone, and dated either from Cretaceous times or soon after. The limestone appears to be bedded almost horizontally but is so seamed with cleavage planes and thrusts that it is difficult to be certain of this. From Chitichun No. 1 has been collected the following rich fauna, identified by Diener :

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[1] *Mem.* XXXII, 170 (1902).

Actinozoa—

**Lonsdaleia* (*Waagenophyllum*) *indica* Waag. and Wentz.,
**Amplexus coralloides* Sow., var-*abichi* Waag. and Wentz. (equivalent to the Upper Productus Limestone form *A. abichi* Waag. and Wentz.)
Zaphrentis beyrichi Rothpl.,
Clisiophyllum sp.,
Dibunophyllum sp.,
Pterophyllum sp.,

Porifera—

**Amblysiphonella* aff. *vesiculosa* de Kon.

Bryozoa—

Fenestella sp.,

Brachiopoda—

**Productus* (*Linoproductus*) *lineatus* Waag.,
* ,, ,, *cora* d'Orb. (probably including *P.* (*L*) *aagardi* Toula, var. *implicata* Reed),
* ,, ,, *cancriniformis* Tschern.,
* ,, (*Ruthenia*) *purdoni* Dav., var. *circularis* Reed (Diener's "*P. abichi* Waag.").
* ,, (*Dictyoclostus*) cf. *subcostatus* Waag.,
* ,, ,, cf. *inca* d' Orb.
* ,, ,, cf. *transversalis* Tscherr. (Diener's "*P. semireticulatus* Mart."),

,, (*striatifera*) *mongolicus* Dien.,
,, *chitichunensis* Dien.,
,, *narastanensis* Dien.,
**Marginifera gragiosa* (Waag.)
* ,, cf. *morrisi* Chao (Diener's "*M. typica* Waag."),
Aulosteges tibeticus Dien.
**Lyttonia* ("*Leptodus*") *nobilis* Waag.,
**Spiriferina* (*Spiriferinella*) *cristata* Schloth. (*octoplicata* Sow.), var. *fastigata* Schellw. (?*S.* (*S.*) *bilotenis* Reed, var. *curta* Reed).
* ,, (*Mansuyella*) *margaritae* (Gemm.),
**Spirifer* (*Choristitella*) *wynnei* Waag.,
* ,, (*Neospirifer*) *musakheylensis* Dav.,
,, *tibetanus* Dien.
**Martinia* cf. *glabra* Mart.,
* ,, *elegans* Dien. (? a variety of *M. distefanoi* Gemm.),
,, *nucula* Rothpl.,
* ,, *corculum* (Kut.),
* ,, *acutomarginalis* Dien. (probably the equivalent of *M. semiramis* Gemm.),
,, *contracta* Meek and Worthen,
**Athyris* (*Cleiothyridina*) *royssii* Lev.,
* ,, *capillata* Waag.,
* ,, *subexpansa* Waag.,
,, *expansa* Phill.,
**Hustedia grandicosta* (Dav.) (probably the equivalent of *H. remota* Eichw.),
**Uncinella* cf. *indica* Waag.,
**Spirigerella derbyi* Waag., var. *acutiplicata* Waag.,
,, *grandis* Waag., (*S. timorensis* Rothpl.)
,, *pertumida* Dien.,
Enteletes tschernyschewi Dien.,
* ,, *waageni* Gemm.,
* ,, *subaequivalvis* Gemm.,
**Uncinunellina jabiensis* (Waag.), (found also in north Sikkim).
* ,, *theobaldi* (Waag.)
**Terebratuloidca* cf. *depressa* Waag.
**Camarophoria purdoni* Dav.,
,, ,, var. *gigantea* Dien.,
,, aff. *cuneiformis* Reed,

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[1] *Pal. Ind.* Ser. XV, Vol. I, Pt. 5 (1903), some modifications have been made.

**Camarophoria globulina* Phill.,
,, cf. *semiplicata* Gemm.,
,, aff. *crumena* Mart.,
**Hemiptychina himalayensis* (Dav.) (cf. Reed's variety *obligata*).
* ,, *sparsiplicata* Wagg. (Diener's "*H. himalayensis*, var. *sparsiplicata*").
* ,, *inflata* Waag.,
* ,, (*Beecheria*) *sublaevis* Waag., (Diener's "*H. himalayensis*, Var. *sublaevis*").
Dielasma (*Heterelama*) cf. *biplex* Wagg.
,, cf. *elongatum* Schloth.,
* ,, *plica* Kut., (probably Reed's variety *arcuata*).
,, aff. *hastaeforme* De Kon.,
Notothyris triplicata Dien.,
,, cf. *subvesicularis* (Dav.),
*(?*Gefonia*) *mediterranea* Gemm. (or a variety).
,, *exilis* Gemm.,
,, *walkeri* Dien.,
,, *revocata* Reed.
**Richthofenia* sp.

Lamellibranchiata—
**Aviculopecten* aff. *jabiensis* Waag.,

Gastropoda—
Naticopsis sp.

Cephalopoda—
Stacheoceras trimurti Dien.,
Nautilus (*Domatoceras*) *hunicus* Dien.,
**Xenaspis carbonaria* Waag., ("*Xenodiscus carbonarius*").
**Cyclolobus walkeri* Dien.

Trilobita—
Phillipsia middlemissi Dien.,
Cheiropyge himalayenises Dien.

Among the three small blocks east of Chitichun No. 1, one has yielded "*Productus semireticulatus*" and is therefore probably of the same age as the Chitichun rock ; it is described as of sufficiently large size to preclude its having rolled down from the eastern slope of the Chitichun peak.

Exotic Block No. 9, which has a volume of at least 300 cubic feet, is seen in the more southerly of the two branches on the upper Kiogarh river, near the camping ground of Malla Sangcha, resting mostly on flysch of upper Cretaceous age. From it have been collected some 44 species, three-quarters of which are identical with Chitichun forms. Again, brachiopods predominate both in number of species and in number of individuals. The forms not found on Chitichun are :

Brachiopoda—
Productus cf. *undatus* Defr.,
,, *waagenianus* Girty, (or *P. eucharis* Girty).
**Marginifera helcia* Abich.,
**Scacchinelta* sp.,
Orthothetes kraffti Dien.,
**Spirifera* (*Neospirifer*) aff. *marcoui*, Waag.,
Squamularia cf. *dieneri* (*Schellw.*),
Spirigerella derbyi Waag., var. *compressa* Reed,
Entetetes cf. *elegans* Gemm.,
Rhynchonella aff. *hofmanni* Krot.,
**Notothyris minuta* Waag.,
,, *ovalis* Gemm.,

Lamellibranchiata—

Aviculopecten cf. *hiemalis* Salt.,
Leiopteria sp.,
Lima aff. *retifera* Shum.

Gastropoda—

**Naticopsis khurensis* Waag.,
**Bellerophon* aff. *pholitus* Waag.,
Pleurotomaria ? (*Trepospira*) *hunica* Dien.
*Salt Range form.

The Chitichun crag and No. 9 Block are evidently derived from the same formation and the two lists of fossils given above may be combined into one fauna. The presence of the ammonite, *Stacheoceras* points to an age younger than the Upper Carboniferous while *Xenaspis carbonaria* and the species of *Cyclolobus* would seem definitely to bring the level of this fauna above the Artinskian ; at the same time, the two trilobites corroborate the evidence of the fauna as a whole against any high horizon in the Permian. Nearly half the brachiopods are identical with species in the Middle Productus Limestone of the Salt Range, and the Chitichun fauna is referred by Diener to the upper portion of this stage.[1]

BAXA SERIES OF DARJEELING AND BHUTAN.

In the foot-hills of Bhutan in the eastern Himalaya, a series of beds named after the hill-fort of Baxa has been distinguished, composed chiefly of variegated slates, quartzites and dolomite, the latter being the most prominent member of the succession and some 1,500 feet in thickness. The dolomite is described as generally massive with obscure bedding, but frequently shaly and passing at times into a dark grey slate ; it is light grey or rarely white, saccharoidal, and characterised by nests of more coarsely crystallised calcite and drusy cavities lined with the same material, scattered through it. This main band of dolomite is traceable from the Rehti to the Tursa, and again for some miles east of Baxa[2] ; owing to the softness of the rocks above and below, it gives rise to a bold ridge sometimes as much as 3,000 feet in height. The assemblage also includes dolomite irregularly interbanded with jasper, an association which shows well the sharp, small-scale folding so common in the Baxa series. Forming part of the sequence is a strong band of quartzites and quartz schists, some of the latter being graphitic ; carbonaceous slates have also been observed.

The total thickness of the Baxas is unknown since its base is nowhere seen and its upper boundary is probably a thrust. This series lies between the Daling beds and the Damudas, but across the Darjeeling boundary to the west its outcrop becomes very attenuated and disappears before the Mo Chu is reached, the Dalings forming a broad belt between the Darjeeling Gneiss and the Damuda rocks. The Dalings appear to overlie the Baxas and the Damudas, all dipping steeply towards the centre of the mountain chain. For this reason and in view of the degree of metamorphism shown by some of its beds, the Baxa series was referred provisionally to the early Palaeozoic or Purana, but the succession is—in part at least—inverted by overthrust, a feature so characteristic of the Himalaya ; the extent of metamorphism is an unreliable age-indicator in a region which has suffered late and intense disturbance. Nonetheless, although the Dalings are undoubtedly lower in the stratigraphical scale than either the Baxas or Damudas, the superposition of the Baxas over the Damudas would appear to be a normal uninverted sequence, if the former are correctly equated with the Krol series of the north-western Himalaya. Mallet, who first described the succession, noted points of resemblance between the Baxa series and the Krol series, and, in fact, suggested a Gondwana age, and the evidence available seems just as much in favour of such a correlation as of the assignment of the Baxas to the Purana.

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[1] *Pal. Ind.* Ser. XV, Vol. I, Pts. 3 and 5 (1897 and 1903). For further information concerning the Chitichun area, reference may be made to the work of Heim and Gansser. [*Denks.* chr. dar Schweiz. Nature. Gesells. Bd. 73, Abh. 1, 157 (1939)].

[2] F. R. Mallet. *Mem.* XI, 34 (1874).

The Baxa and Daling series were recognised and mapped indistinguishably as Purana in the more eastern parts of Bhutan by Dr. Pilgrim who was inclined to refer to the former a massive white quartzite not less than 10,000 feet in thickness which he traversed three times between the Siwalik boundary and the Kuru Chu ; these quartzite exposures form precipitous cliffs of 5,000 feet on the western side of the Pagla Dia. Whatever the age of the quartzite may be, the extension of the Baxa series to these parts is made certain by the occurrence of the dolomitic limestone with the characteristic nests of calcite described above. In places, the dolomite has undergone extensive silicification with the production of thick beds of a powdery white jasper. The dolomite may be left in the form of thin bands or lenticles in the jasper, while in other places it is the dolomite which predominates, the jasper occurring in thin layers therein. The dolomite passes into thin-bedded calcareous slates, and below these are flaggy quartzites and quartz schists wholly different in appearance from the massive quartzites mentioned above ; alternating with these quartzose beds are thin bands of dolomitic limestone which pass into more slaty beds. On the northern side of the Kenga La, Pilgrim records a thickness of 1,500 feet of massive dolomite. Although the dolomites are seen to dip under the massive quartzites of the Manas river, there is reason to believe that the latter are the older, as they are thought to be in western Bhutan, and have been thrust over a sharply folded syncline of the dolomitic assemblage. Loose specimens of rock gypsum are recorded from some of the stream beds of this area and are believed to have been derived from the Baxa series. The soil amid the dolomite crags nourishes an abundance of the beautiful *Saxifraga ligulata* and the somewhat rare ground orchid *Cypripedium farninruma*[1].

Two belts of a dolomitic series were traversed by Dr. Coggin Brown during the Abor Hills expedition up the Dihong (Dihaug) river, some 250 miles, E.N.E. of the last-mentioned locality. The belt near the plains occur in the "Abor Volcanic series" but is extremely badly exposed ; the rocks include brecciated limestone, slates and phyllites, all typically showing contortion. Around the village of Komsing are highly contorted purple slates, while pieces of slaty dolomitic limestone are to be picked up on the neighbouring hill-sides.

The inner belt commences at the precipitous descent from a 4,000-foot watershed to the Sisi river over " metamorphosed and very brecciated dark bluish-grey dolomites in thick beds, with an occasional layer." Associated with the dolomites, which are repeated near Rikor village, are dark, fine-grained, biotite schists, quartzite bands, sericite schists and micaceous phyllites, in all of which long lenticles of quartz are common[2].

The dolomites of these two belts may be provisionally assigned to the Baxa series, but such an allocation cannot be made certain until the detailed structure of these hills has been determined.

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[1] Carl Diener *Rec.* XXXIV, 25-29 (1906).

[2] *Rec.*, XLII, 246-251 (1912).

GONDWANAS OF THE EASTERN HIMALAYA.

Extent and mode of occurrence.—A narrow belt of Gondwana rocks has been noted in the lower slopes of the eastern Himalaya at various points between the Arun river in Nepal and the Dihong (Dihang) Brahmaputra in the Abor country bordering the plains of upper Assam; probably the belt extends further to the west and east of its observed occurrences. The greater part of this belt belongs to the Lower Gondwana, but in the Abor hills the Upper division is represented by a thick series of volcanic beds which have been correlated provisionally with the Rajmahal traps; at its eastern end also, rocks of Gondwana facies are accompanied by fossiliferous limestones with an "anthracolithic" (*i.e.*, probably Lower Permian) fauna. In some places at least, the succession is inverted and its lower limit in Bhutan and the Abor hills is described as a thrust-plane, up which the Gondwanas have been thrust over the Siwalik Tertiaries.

Nepal.—Coal-bearing Gondwana rocks have been found by Dr. Sutton Bowman in eastern Nepal, at the confluence of the Sun Kosi and Arun rivers.[1]

Darjeeling.—The most extensively studied portion of this eastern Himalayan belt is that of the foot-hills of the Darjeeling district, where the succession is overthrust by older rocks and consists of an outcrop from 600 feet to a mile in width.[2] This usually narrow band stretches from Pankabari eastwards across the Tista and, after a gap of six or seven miles caused partly by the beds being cut out by a fault but chiefly in all probability by concealment beneath alluvial deposits, has been traced as far as the Jaldoka ("Juldhoka") river or De Chu. From Pankabari to near Dalingkot, the Gondwanas occur between the ancient Daling slates above and the Siwalik Tertiaries below; farther east, in the Mo Chu area, a thin band of the so-called Baxa series makes its appearance between the slates to the north and the coal-bearing Gondwanas to the south. There are many minor contortions in the beds, but the general dip is towards the heart of the range and is mostly steep.

The bulk of the Gondwana beds belong undoubtedly to the Damuda series; they were thought by Mallet to show somewhat greater resemblances to the Raniganj stage than to the Barakar, but the discovery by Sir Fox of a boulder bed above Tindharia Railway Station demonstrates the presence of the Talchir and makes it a little more probable that the rest of the sequence belongs to the Barakar.[3] There is considerable variation in the degree of metamorphism and some of the rocks are said to be as unaltered as their homologues in the Damuda valley; in most cases, however, they have suffered the same crushing and disturbance which have affected the other rocks of the area, the result being the conversion of the sandstones into quartzites, the shales into splintery slates and the carbonaceous shales into carbonaceous or graphitic schists. Such metamorphosed varieties are apt to be confused with the older Daling beds, among which graphitic schists are known to occur. Most of the Damuda shale is carbonaceous; the dark grey variety is generally micaceous and has yielded some well-preserved plant remains, among which have been identified *Glossopteris indica, G. sp.*, abundance of *Vertebraria*, *Phyllotheca* and, according to Hooker, *Schizoneura*.

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[1] *Rec.* LXIX, 154 (1935).

[2] F. R. Mallet. *Mem.*, XI, 14 (1874).

[3] *Mem.* LIX, 9 (1934).

The beds include several seams of coal, which is invariably greatly crushed and has assumed a flakiness detracting much from its economic value. In some cases thrusting seems to have located itself along the soft, yielding horizon of a coal seam. At least ten seams, each over five feet in thickness, are recorded by P. N. Bose,[1] but the best of these is but eleven feet thick. The occurrence of coal in the Darjeeling district makes it possible that coalfields exist beneath the Alluvium between that district and the Rajmahal area.

A few intrusive dykes of mica periodotite complete the resemblance to the Damuda valley exposures ; the most coarsely grained variety of this rock comes from the Darjeeling area.

Bhutan.—Passing eastward we come to Bhutan. In the eastern parts of this State coal is reported from the Manas river. Further east, near Diwangiri, although no actual coal has been observed, there are thin beds of carbonaceous shale belonging no doubt to an exposure of Damuda rocks.

Still further east, Damuda rocks with coal seams were recognised by Pilgrim in the Bor Nadi and continue eastwards across the Kala Pani which is close to the eastern boundary of Bhutan. In the Kala Pani area, the total thickness exposed is about 500 feet. The lowest beds consist of fine, soft sandstones with interbedded coal seams which, at one time continuous, have been squeezed out along thrust-planes into small isolated lenticles. Some half-a-dozen seams or more are represented in this way but the thickest observed was only three feet and thinned out to zero within a distance of twenty feet. As in the Darjeeling area, the coal is crushed and flaky, the result being a low volatile percentage. The upper 300 feet are composed for the most part of hard, quartzitic sandstones with frequent thin partings of carbonaceous matter, beds of shale which are often carbonaceous, and another thin coal seam.[2]

Aka Hills.—In the Aka hills, the Damudas are again seen north of Tezpur, in the upper waters of the Bhareli (Boroli ; Borholi) river which for some distance runs along the strike of these beds. The Baxas appear to be absent and the beds, comprising narrow bands of hard, grey quartzitic sandstones interstratified with carbonaceous shales and seams of coal, all much crushed and contorted, lie steeply dipping between the Dalings above and the Tertiaries below. The thickest seams of coal is only 1½ feet thick.[3]

Dafla Hills.—In the Dafla hills, the Damuda coal measures, consisting of almost vertical shales, often carbonaceous, interstratified with dark, close-grained sandstones, have been noted by Godwin Austin in the Dikrang river below Shikhi ; the carbonaceous varieties of the shale occasionally pass into 5 to 6 feet seams of coal which is much crushed and splintered[4] ; a green trap amongst these beds probably represents an intrusion, which may be of the same age as the trap found in Abor hills.

No fossils have been discovered *in situ* in the Mount Everest Limestone, but what are believed to be erratic blocks of that formation have yielded a large unidentifiable involute nautiloid, a quinquepartite crinoid stem, and an organism strongly reminiscent of certain sycone sponges which made their appearance in the Carboniferous and became common in the Permian and Trias. The position of the Mount Everest Limestone immediately below the Lachi series, whose upper stages are Upper Permian and whose lowest stage may be as old as Middle Carboniferous, sugests a Middle or Lower Carboniferous age. This conclusion is more or less in agreement with the suggestion of Mr. Wager that the Mount Everest Limestone should be correlated with the Baxa series of Bhutan which may be of Carboniferous age.[1]

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[1] *Rec.* XXIII, 237 (1890).
[2] C. Diener. *Rec.* XXXIV, 31 (1906).
[3] T. H. D. La Touch. *Rec.* XVIII, 122 (1885).
[4] *J. A. S. B.* XLIV, Pt. 2, 37 (1875).

A limestone, occurring below representatives of the Lachi series on the Lhonak range south of Kampa Dzong has been linked up with the limestone mapped by Dr. Heron north of Rongbuk.

The series of shales, quartzites and sandstones on the Lachi ridge northeast of Kinchinjunga in Sikkim has been designated as Lachi series by Wager and has yielded fossils from two horizons separated from each other by 600 feet of pebble beds for which a Talchir age has been suggested. The sequence is as follows :—

Quartzites	400 feet
Fossiliferous sandstone	300 ,,
Pebble Beds	600 ,,
Limestone and shales with comminuted corals, crinoid ossicles and other fossils	50 ,,
Quartzite and shales	600 ,,
(Mount Everest Limestone series-base not seen)	..

The lower fossil horizon has yielded : *Straparollus lachiensis* Muir-Wood and Oakley, *Ellipsellipsopa* sp., *Products* sp., an athyrid, and *Spiriferellina* sp., all of uncertain age but evidently belonging to the Carboniferous or Permian. If the Pebble Beds are rightly correlated with the Talchir and Blaini, the lower fossil bed must be either Upper or Middle Carboniferous in age, though there appears to be no hiatus between the Pebble Beds and the overlying fossiliferous sandstones from which has been collected a shallow-water fauna of Upper Permian (Kazanian) age ; it seems more likely that the Pebble Beds are Permian. The fauna from the fossiliferous sandstone, according to the determinations of Dr. Helen Muir-Wood and Dr. K. P. Oakley with slight modifications comprises the following :[2]

Goniocladia sp.,
Rhombopora cf. *circumcincta* Reed (species found in the southern Shan States),
Geinitzella [*Batostomella*] sp.,
Fenestella (*Fenestrellina*) aff. *fossula* (Lonsd.) (species found in the Upper Marine series of Tasmania),
'*Poteriocrinus*' sp.,
An orthothetid,
Productus (*Dictyoclostus*) cf. *subcostatus* Waag. (species found in the Salt Range),
    ,, (*Linoproductus*) cf. *cora* d'Orb. (a variety of the species is found in the Salt Range),
    ,, (*Ruthenia*) *purdoni* Dav. (a variety of the species found in the Salt Range),
    ,, (*Pustula*) sp.,
Marginifera cf. *gratiosa* (Waag.) (species found in the Salt Range),
    ,, *himalayensis* Dien. (the commonest species of the Productus Shales; found in Kumaon, Spiti, Kashmir and the Karakoram),

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[1] Dr. K. P. Oakley. *Pal. Ind.* New Ser. Vol. XXXI, *Mem.* 1, 70 (1941).
[2] *Pal. Ind.* New Ser. Vol. XXXI, *Mem.* 1 (1941).

Chonetes wageri Muir-Wood & Oakley,

Camarotoechia sp.,

Uncinunellina jabiensis (Waag.) (found also in the Salt Range, Tibet and Armenia ; genus well represented in the early Middle Permian of India and south China).

Spirifer (*Neospirifer*) *musakheylensis* Dav. (probably a variety),

,, (*Spiriferella*) *rajah* (Salt.) (said to occur in Chitral, Kashmir, Spiti, Kumaon Mongolia and Timor),

Syringothyris lydekkeri (Dien.) (found in Kashmir, the Karakoram, China and Indo-China),

Leda (*Nuculana*) sp.,

Parallelodon [*Macrodon*] aff. *tenuistriatum* (Meek & Worthen), (species found in the United States and Manchuria),

Pleurophorus sp.,

Aviculopecten hiemalis Salter (A Productus Shales species ; found also in the Karakoram and South Timan),

,, cf. *leniusculus* (Dana) (Species found in the Upper Marine series of New South Wales),

Pleurotomaria (? *Cyclites*) aff. *orientalis* Roem. (non Kratow) (species found in the Permian of Sumatra),

By far the most abundant fossil is *Spiriferella rajah* ; the presence of this species and of *Marginifera himalayensis* and *Neospirifer musakheylensis* indicates an Upper Permian age, and the horizon can be assigned with confidence to some part of the Producuts Shales. The pebbles of the Pebble Beds consist mainly of dark quartzite and pink limestone and are sparsely scattered throughout the whole stage, the largest having a diameter of about four inches ; the rest of the rock is described as a grit composed of ungraded angular quartz and felspar grains set in a very fine paste of quartz and mica. The pebbles exhibit no glacial striae but are reminiscent in many ways of the Talchir Boulder Bed. Such a correlation would necessitate the inference of a highly condensed succession if the latter is unfaulted and uninterrupted by any appreciable unconformity.

The limestone found by Hooker on the east side of the Tso Lhamo in north Sikkim belongs probably to the upper part of the Lachi series[1]. From it have been collected : *Monogenerina* sp., hydrozoa, bryozoa, and the doubtful alga, *Solenopora* (*Parachaetetes*) *hookeri* Muir-Wood & Oakley.

Fossils typical of the Productus Shales have been collected from the vicinity of the Kongra La, a pass crossing the Lhonak range, and indicate the presence of the Lachi series.

Lakhimpur district.—Near the mouth of the Subansiri gorge, in the north of the Lakhimpur district of Assam, some boulders have yielded the following marine fauna belonging to some part of the Productus Limestone (Permian). The rock matrix is of two kinds, an arenaceous with badly preserved specimens of : *Productus* cf. *pustulosus* Phill., *Spirifer* sp. ind., *Spiriferina* sp. ind., *Squamularia* cf. *inasequilateralis* (?) Gemm., *Dielasma* aff. *uralicum* Krot. and D. aff. *biplex* Waag., and one composed of hard blue limestone, rich in casts of *Chonetes* cf. *carbonifera* Keys. and including other casts of *Myalina* sp., *Monopteria subansirica* Dien., *Loxonema* sp. *Pleurotomaria* aff. *punjabica* Waag., *Bellerophon* sp., and *Fenestella* sp. [2]. This fossil horizon appears to be close to the younger of the two fossil horizons of the Lachi series in Sikkim.

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[1] *Pal. Ind.* New Ser. Vol. XXXI, *Mem.* 1, 71 (1941).

[2] C. Diener. *Rec.* XXXII, 189-198 (1905).

In the Miri hills, pieces of coal picked up in the Sundri and Subansiri rivers and reported to come from some distance up in the hills may be of Gondwana origin.[1]

Abor Hills.—An outcrop of rocks bearing a close resemblance to the Damudas of the Darjeeling area, about three miles wide, occurs in the Abor hills above Janakmukh, where it is traversed by the Dihong river ; the belt has been again observed a dozen miles or so to the southwest, in the upper part of the Sireng tributary. The beds, which are unfossiliferous, occur above the Siwalik belt, over which they are believed to have been overthrust[2], the commonest types are light coloured indurated sandstones and quartzites, reddish ferruginous shales, carbonaceous shale often with clay iron-stone, septarian nodules, schistose shales and seams of very friable coal crushed out into lenticles.

An interesting discovery made by Dr. Coggin Brown in the Sireng area was the occurrence of boulders of dark blue-grey, slightly arenaceous limestone containing marine fossils indeterminate except for the identification of crinoid ossicles. This is in all probability the same limestone as that composing the boulders found at the mouth of the Subansiri gorge, which yielded the small *Productus* faunas ; according to Coggin Brown, it undoubtedly corresponds to the base of the Gondwanas and therefore marks the position of a point on or near the north-eastern coast of the Gondwana continent.

Another point of interest concerning the Abor Gondwana outcrop is the fact that the Gondwana sequence is succeeded by an extensive series of volcanic rocks, exposed over a width of some twenty-five miles from beyond Renging to near Geku, interrupted in the middle by a six or seven mile band of metamorphic rocks with dolomite. The Abor Volcanics, as they have been called, consist of decomposed traps, apparently interbedded with carbonaceous shales and quartzites precisely similar to the coal-bearing Gondwana rocks further south, which would seem to belong to the Damuda. On the other hand, the traps, which nearly all consist of greyish, greenish or reddish palagonite-bearing basalt, are described as showing great resemblances to the palagonite-bearing traps of the Rajmahal hills. Some of the shales exhibit signs of thermal metamorphism but, whether along one face only, has not been determined. Many of the traps are very amygdaloidal and are accompanied in places by shale-like tuffs and agglomerates containing amygdaloidal pebbles ; there is reason to conclude, therefore, that these volcanic beds are in the main effusions contemporaneous with the sedimentaries among which they occur, and the possibility arises that the series as a whole corresponds to the Rajmahal of Bengal. What its relationship is to the coal-bearing formation immediately to the south remains for further investigation to decide, but it seems highly probable, from analogy with the Darjeeling occurrence, that the lower belt of sedimentaries consists of Damuda rocks. If we accept the presumption that the higher-lying carbonaceous shales and quartzites are truly interbedded with beds of trap having every appearance of being contemporaneous flows of Rajmahal aspect, these sediments and their associated traps may represent the Rajmahal series (early Jurassic) : in this case, the Abor Volcanics and their associated sediments would lie, presumably with an unconformity, masked by the nature of the terrain stratigraphically above the Damuda. If, on the other hand, the upper belt of trap-ridden Gondwanas are equated with the lower belt of probable Damudas, which they so much resemble, and the traps are assumed to be all intrusive, the age of the intrusions may be either Panjal, Rajmahal or Dras (Deccan Trap). The weathering of the trap produces a reddish tenacious clay, but some of the flows are very massive (60 feet) and little weathered, sometimes showing a rough prismatic jointing. Amongst the minerals filling the amygdules are chalcedony, opal, clear quartz, palagonite and epidote.

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[1] J. M. Maclaren. *Rec.* XXXI, 190 (1904).

[2] J. Coggin Brown. *Rec.* XLII, 238 (1912).

Mishmi country.—East of the Abor country, fragments of coal have been picked up in the Dibong (Dibang), *i.e.*, to the east of the Dihong, and stories of smoke and flames seen among the hills may have their origin in burning coal outcrops. No Gondwanas, however, were found by Mr. A. M. N. Ghosh among these hills.[1]

MOUNT EVEREST AREA.

To the north of Mount Everest, a thick series of limestones has been mapped by Heron, forming a continuous E-W band between the crystalline complex of which the mass of the mountain is composed and the Jurassic shales further north and lower down the slope. The formation consists of from 2,000 to 3,000 feet of a very uniform assemblage of thin beds of limestone, usually from one to three feet thick, with shaly partings. The beds have been extensively invaded by granite veins and involved in the crystalline complex in such a way as to make it impossible to demarcate a true boundary. Two outcrops of these rocks have been mapped, but the exposure was probably continuous along the southern margin of the Jurassic shales before the uneven encroachment of the granite magma. As a whole, the limestones have become to a large extent crystalline or have been converted to calc-schists. Streaks of crystalline calcite may represent original fossils, but scarcely anything recognisable remains. The lowest horizons of the series have been more or less obliterated by the granite, but the upper portions dip gently northwards under the Jurassic shales up into which they appear to pass without any visible unconformity.

As to the age of these beds, their situation with regard to the crystalline zone is very similar to that of the Dothak series of limestones and other sedimentaries which were mapped by Sir Henry Hayden between the Chumbi valley and Bhutan and were considered by him to include part or all of the Trias and perhaps one or more of the Palaeozoic systems. There is, however, some evidence, thought not very definite, in favour of an older age. Two sections in the ridges east and west of Hlelung, twenty miles north of the Everest peak, showed at the base of the overlying Jurassic shales, just as they give place to the limestones, a thin ferruginous bed crowded with specimens of *Spirifer* and *Productus* ; from these *Productus* (*Pustula*) sp., *P.* (*Buxtonia*) sp., and *Spirifer* (*Spiriferella*) *rajah* have been identified. Assigning an Upper Permian age to the top of the limestone series, the bulk of it would fall within the Permian of Europe, with perhaps a portion of the Carboniferous.[3]

Mount Everest itself, as we have seen, is made up for the most part of an ancient series of schists and hybrid gneiss, the " Mount Everest Pelitic series " of Mr. L. R. Wager, and probably the equivalent of the Dalings of Sikkim. Overlying this and forming the upper part of the mountain comes the Mount Everest Limestone of the same observer.[1] The basal slabby portion of this consists mainly of yellow schistose limestones approaching marble in the degree of their metamorphism. While these "Yellow Slabs", as they have been called, commence somewhat abruptly and dip northwards at about 30°, the surface of the mountain forms a moderately steep slope of approximately 50°; the result is that these slabs, occurring between about 27,500 and 28,000 feet, have the over-lapping arrangement of the tiles of a roof, a phenomenon which adds to the difficulties of climbing.[2] Above the Yellow Slabs is a band of dark grey, somewhat shattered and altered limestone which, being more resistant than the schistose limestone of the slabs, forms a bold feature with a steeper and in some places overhanging slope. There is little doubt that the topmost 1,000 feet, which form the final pyramid of the mountain, are composed of this limestone.[3] In all probability it forms the summits of surrounding heights such as "North Peak," "Khartaphu," "Peak 23,180", "Gyachung Kang," and "Jongsong.[4]" This is the same limestone series as that mapped by Dr. Heron to the north of Rongbuk and some sixteen miles north of the Everest summit.

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[1] *Rec.* LXIX, 85 (1935).

[2] Helen M. Muir Wood. *Pal. Ind.*, New Ser., Vol. XXXI, *Mem.* 1, pp. 55-57 (1941).

[3] A. M. Heron. *Rec.* LIV, 232 (1922).

CHITRAL, GILGIT AND THE PAMIRS.

In the Chitral valley opposite Reshun, as well as above the village of Shugrame the Upper Devonian rocks are overlain by a thick series of paper shales, needle shales and quartzite; amongst the shales is a thin bed of crinoidal limestone. Further back in the hills, the Upper Devonian and overlying series are repeated by a fault, the quartzite forming the ridge above Lun village.

Further to the northeast, behind Lasht, in the Yarkhun valley, the beds over the Devonian constitute a very thick series of black slate and white quartzite forming the high ridge behind *i.e.*, to the north of the village. This series extend up to the snow-line, where it is in contact with intrusive granite, and continue along the Yarkhun valley all the way to Petus.[5]

North of the last-mentioned locality, the shale and quartzite series is seen continuously for a considerable distance along the ridge separating the Dasht-i-Boroghil from the Yarkhun valley. Here the shale and quartzite pass up through thinly-bedded limestone full of crinoid stems into further shale and shaly limestone. From this locality a rich fauna has been collected from six or seven horizons by Hayden and described by Cowper Reed.[6] The principal features of the assemblage are the abundance of *Fusulina*, the absence of cephalopods, the rarity of lamellibranchs and gastropods with the exception of members of the Bellerophontacea, and the preponderance of brachiopods. The corals, which are almost entirely restricted to the third horizon from below, are of special interest owing to the presence of *Lonsdaleia salinaria*, and in the highest horizon of *L. indica*, both of them Salt Range species; in addition, the following forms from the Productus Limestone of the Salt Range have been recognised: *Productus* (*Linoproductus*) *lineatus*, *P.* (*Striatifera*) *compressus*, *Spirifer* (*Neospirifer*) *musakheylensis* ?, *Squamularia* (*Neophricodothyris*) *asiatica*, *Spiriferina* (*Spriferellina*) *cristata*, *Athyris*

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[1] This should not be confused with what Mr. Wager calls the "Lower Mount Everest Limestone" which occurs below the Mount Everest Pelitic series.

[2] H. Ruttledge. "Everest 1933", 322.

[3] Odel calls it a dark calcareous schist, very fine-grained and compact, with quartz and biotite. *Ibid*. 322.

[4] *Ibid*. Dyrenfurth "Under Expedition," 301 (1931).

[5] H. H. Hayden. *Rec.* XLV, 290 (1915).

[6] *Pal. Ind.* New Ser. Vol. VI, *Mem.* 4, p. 115 *et. seq.* (1925).

subexpansa and possibly others. With the Zewan beds of Kashmir the formation has a few forms in common but here again they consist of brachiopods of long range. In spite of some differences from the fauna of the Productus Limestone and its equivalents in Kashmir or the more central parts of the Himalaya, the Chitral fauna is in all probability Lower Permian, at the same time it has a resemblance, both in facies and composition, to the Fusulina limestones of the Urals, the Timan Mountains and central Asia (southern Tian Shan), especially to the topmost or *Schwagerina* stage with which it has several species in common. The complete list of species from the whole succession of beds at this locality is as follows :—

Foraminifera—
S. *Fusulina* (*Schellwienia*) *verneuili* Möll., var.,
S. ,, ,, *lutugini* Schellw.?
S. *Schwagerina* *princeps* (Ehrenb.) (a widely distributed form),
,, *fusiformis* Krot.,
Endothyra sp.,
Valvulina sp.,

Actinozoa—
S. *Orionastraea phillipsi* McCoy,
Michelinia mansuyi Reed,
Lonsdaleia (*Waagenophyllum*) *indica* Waag & Wentz.,
,, (*Wentzelella*) *salinaria* Waag & Wentz.,

Crinoidea—
Graphiocrinus yarkundensis Reed.

Bryozoa—
Fenestella aff. *eichwaldi* Stuck.,
,, aff. *lahuseni* Stuck.,
S. *Polypora* aff. *kolvae* Stuck.,

Brachiopoda—
Derbya baroghilensis Reed.
S. *Productus* (*Linoproductus*) *aagardi* Toula.,
S. ,, ,, *cancriniformis* ? Tschern.,
S. ,, ,, *lineatus* Waag.,
,, ,, *tenuistriatus* de Vern.,
S. ,, (*Striatifera*) *compressus* Waag. (=*P. anomalus* Tschern.)
S. ,, (*Dictyoclostus*) *transversalis* Tschern.,
S. ,, (*Proboscidella*) aff. *kutorgae* Tschern.,
,, *inassuetus* Reed.,
S. ,, (*Tschernyschiella*) *porrectus* Kut.,
,, *vindicatus* Reed,
,, (*Dictyoclostus*?) *volgensis* Stuck, var.,
S. ,, cf. *pseudoaculeatus* Krot.,

S. ,, aff. *tartaricus* Tschern. (probably identical with *P. suborientalis* Reed),
S. *Marginifera* cf. *lebedevi* Tschern.,
S. *Chonetes variolata* d'Orb., var. *baroghilensis* Reed,
,, *blanfordi* Reed,
,, *costata* Stuck., var. (possibly identical with *C.* (*Plicochonetes*) *paeckelmanni* de Terra var. *buriensis* Reed, from the Upper Productus Limestone),

Brachiopoda—*contd.*

S. *Chonetes pseudovariolata* Nik.?
,, *sinuosa* Schellw.,
S. *Spirifer* (*Neospirifer*) *fasciger* Keys., var. *paucicostulata* Reed,
,, (*Spiriferella*) *musakheylensis* Dav.,
,, ,, *rajah* Salt.,
S. *Martinia sokolovi* Tschern.,
S. *Spiriferina* (*Spiriferellina*) *cristata* Schloth.,
,, *holdichi* Reed.,
Martiniopsis aff. *lulugini* Tschern.,
S. *Comarophoria superstes* (de Vern.),
,, cf. *pentameroides* Tschern.,
S. *Ambocoelia planocondvexa* (Shum.),
S. *Athyris* (*Cleiothyridina*) *gerardi* Dien.?
,, ,, *ailakensis* Reed?
,, ,, *capillata* Waag.?
,, ,, *royssii* L'Ev.?
,, ,, *subexpansa* Waag.,

Lamellibranchiata—

S. *Girtypecten chitralensis* (Reed), (found in the Lower Productus Limestone),
Palaeolima subfuscata Reed,
,, *retiferiformis* Netsch.,

Gastropoda—

Pleurotomaria (*Worthenia*) *haydeni* Reed,
,, ,, *chitralensis* Reed,
Strophostylus cf. *remex* (White),
Euomphalus (*Phymatifer*) *pernodosus* (Meek & Worth).
Bellerophon crassoides Reed,
,, (*Waagenella*) *burrardi* Reed,
,, ,, *mcmahoni* Reed,
,, ,, aff. *portlocki* de Kon.,
Bucania sp.,
Warthia aff. *brevisinuata* Waag.,
,, aff. *polita* Waag.

Plantae—

Girvanella sp.

S.= Identical with or allied to forms found in the Russian *Schwagerina* stage.

The genera *Lyttonia* and *Richthofenia*, which are peculiarly characteristic of the Asiatic "Permo-Carboniferous", (Lower Permian) are unrepresented in the above fauna.

From a loose moraine at the same locality of Baroghil Ailak a somewhat similar assemblage was collected which included the following, among which are several additional Russian Schwagerina Limestone forms:

Foraminifera—

S. *Fusulina* (*Schellwienia*) *krotowi* Schellw.,
,, ,, cf. *longissima* v. Möll.,
,, ,, cf. *lutugini* Schellw.?
S. ,, ,, *mölleri* Schellw., var. *chitralensis* Reed,
,, ,, *verneuili* v. Möll., var. *yarkhunensis* Reed,
,, ,, cf. *kraffi* Schellw.,
Schwagerina princeps (Ehrenb.),

Brachiopoda—
Orthis (*Schizophoria*) cf. *juresanensis* Tschern.,
S. *Orthotichia morganiana* Derb.,
Orthothetina aff. *bashkirica* Tschern.,
Productus (*Dictyoclostus*) *gruenewaldti* Krot., var.,
,, ,, *uralicus* Tschern.,
,, cf. *pyramidalis* Netsch.,
S. *Chonetes mölleri* Tschern., var.,
,, *latesinuata* Schellw., var. *retrorsistria* Reed,
S. *Squamularia* (*Neophricodothyris*) *asiatica* Chao ("*Reticularia lineata*"),
S. *Spiriferina* (*Mansuyella*) aff. *holzapfeli* Tschern.,
,, *multiplicata* Sow., var. (cf. *S.* (*Paraspiriferina*) *ghundiensis* Reed, from the Middle Productus Limestone),
Dielasma acutangulum Waag.,
S. ,, aff. *juresanense* Tschern.,
S. ,, cf. *supracarbonicum* Tschern.?
S. *Notothyris nucleolus* (Kut.), var *baroghilensis* Reed,
Athyris (*Cleiothyridina*) *subexpansa* Waag.,
S.=Identical with or allied to forms found in the Russian *Schwagerina* stage.

Lamellibranchiata—
Entolium cf. *aviculatum* Swallow,

Gastropoda—
Straparollus cf. *laevigatus* L'Ev.,
Bellerophon cf. *hiulcus* Mart.,
Stachella cf. *semiaurita* Waag.,
Euphemus carbonarius (Cox),
Warthia aff. *brevisinuata* Waag.,
Pharkidonotus aff. *percarinatus* Conr.,

Scaphopoda—
Plagioglypta cf. *prisca* Munst.

Four miles north of Baroghil Ailak was found an internal cast of *Euphemus*(?) [*Gastrioceras* ?] *baroghilensis* Reed. Fusulina limestones and shales have been identified by Tipper in the neighbourhood of Tirich Mir in Chitral; some shales further to the southwest have yielded *Fenestella* and *Syringothyris*.[1] *Fusulina* also occurs further along the strike in the Lond Ku valley. Elsewhere, the Fusulina beds, lying almost flat, appear to have been let down by block faults between the Devonian and the Sarikol shales (? Trias).

In the Yasin valley of Gilgit, a grey, splintery, massive, unfossiliferous limestone is overlain by a shaly limestone with large numbers of bryozoa, *Fusulina* and crushed bands of *Productus*, the beds striking E-W. The scanty fauna is different from the fauna of the other localities, but its distinct facies may be due as much to environmental conditions as to difference in age, and there is good evidence in favour of an age very close to that of Baroghil fauna. The following species have been recognised in the Yasin beds :—

Neoschwagerina cf. *craticulifera* Schwager, (species typically Uralian),
Zaphrentis ? sp.,
Crinoid stems,

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[1] *Rec.* LIV, 56 (1922).

Fistulipora yasinensis Reed (closely allied to forms in Russian Upper Carboniferous and Lower Permian),
Taeniodictya darbandensis Reed,
Aseopora cf. *nodosa* Fisch. (a characteristic Russian species),
,, cf. *trautscholdi* Stuck (a characteristic Russian species),
Polypora darkotensis Reed,
Fenestella sp.,
Enteletes cf. *hemiplicatus* Hall,
Bellerophon nodulatum Reed.

Amongst the calcareous and slaty rocks around Khaibar, a village in the Hunza valley, is a limestone with doubtful *Fusulina*, giving rise to cliffs several thousand feet above the river ; in places the section with its intrusions of trap recalls that of the Baroghil Pass.

Near Ak Baital in the Pamirs, Upper Devonian rocks appear to pass up into a mass of broken limestone, shale, sandstone and finally a conglomerate, all of which weather in brilliant colours including red, yellow, grey and black ; this series is described as being associated with diabase and much gypsum. Hayden's Pamir Limestone may include horizons from basal Permian to Jurassic.[1]

The Fusulina Limestone is again met with near the Koksu ford at Irekeshtam in Russian Turkistan.

CENTRAL TIBET.

Limestone with Upper Carboniferous fossils was met with by Sir Henry Hayden in central Tibet at various points between the neighbourhood of Wom-po and that of Phong-do-Dzong, indicating an outcrop, continuous or otherwise for over two-hundred-and-eighty miles, with an orientation which must be E.-W., W.N.W.-E.S.E. or somewhere between. This limestone is seen as a dark grey, much altered, fossiliferous rock full of calcite veins, on the north side of the valley between A-chen-tsong and Shen-tsa-dzong, the latter town being situated about a hundred and seventy-five miles W.N.W. of Lhasa. In places, the limestone appears to be underlain by a volcanic series resembling the Panjal Volcanics and including both ashes and lavas ; a specimen of one of the latter proved to be a serpentinised amygdaloidal basalt. These volcanic beds are seen to the south of the above-mentioned valley, where their upper members are associated with pebble beds, sandstones, etc.[2] To the northwest of Shen-tsa-dzong, the limestone is described as overlying quartzites and shales, and to the latter assemblage probably belongs the red quartzite seen to the northeast of the same town. Fossils were collected by Hayden from ten localities, several of them from the limestone ridge east of Shen-tsa-dzong, but the majority were obtained from a short distance east of Wom-po. Hayden considers that the limestone may range up into the Trias, but the fossils are all Upper Carboniferous forms (Uralian) ; in most cases, the specimens collected were very small in number, fragmentary and often ill-preserved. The following forms most of which belong to well-established species have been identified by Dr. Cowper Reed.[3]

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[1] *Rec.* XLV, 315 (1915).

[2] A. L. Coulson. *Rec.* LXVII, 333 (1933).

[3] *Pal. Ind.* New Ser. Vol. XVI, 1-3 (1930).

Feraminifera—

Schwagerina princeps Ehrenb.,
,, *fusiformis* Krot (form found in Russia, Chitral, Yunnan and the Carnic Alps).
Fusulina (*Schellwienia*) sp.,
Fusulina cf. *biconica* (Hayas)?

Actinozoa—

Lonsdaleia (*Wentzelella*) *salinaria* Waag. & Wentz. (a form found in the Salt Range, Chitral, Indo-China and Tenasserim),
,, cf. *virgalensis* Waag. & Wentz.,
,, aff. *enormis* Ozawa.,
,, (*Waagenophyllum*) cf. *indica* var. *akagoensis* Ozawa.,
,, *tibetica* Reed,
Syringopora haydeni Reed,
,, *catenoides* Reed,
,, *gemina* Reed,
Campophyllum haydeni Reed,
Chonaxis cf. *pongouanensis* Mansuy (species found in Indo-China),
Zaphrentis (?) sp.,
Amplexus cf. *abichi* Waagd. & Wentz. (species found in the Salt Range),

Bryozoa—

Polypora cf. *subquadrata* Toula (species found in the Barents Islands and Russia),
,, cf. *bifurcata* Keys (species found in Russia),
,, cf. *porosa* Eichw. (species found in Russia),
Ramipora uralika Stuck. (species found in Russia),
Geinitzella cf. *columnaris* Schloth. (species found in the European Permian),
,, cf. *arbuscula* Eichw. (species found in Russia),
Fenestella cf. *elegantissima* Eichw.

Brachiopoda—

Productus (*Dictyoclostus*) cf. *grunewaldti* Krotow (found in China and the Shan States)
,, (*Hordonia*) cf. *timanicus* Stuck. (found in the Urals, Spitzbergen, Bear Island and Indo-China),
,, (*Buxtonia*) aff. *juresanensis* Tschern. (found in Russia, Indo-China and perhaps the Carnic Alps),
Marginifera lebedevi Tschern., var. (species found in Russia),
,, (?) *equivocalis* Reed,
Camarophoria kutorgae Tschern., var. nov.,
,, cf. *globulina* Phill. (found in Russia, the Salt Range, and at Chitichun),
Squamularia rostrata Kut. (found in the Urals and China),
,, cf. *asiatica* Chao ("*Reticularia lineata*"),
Syringothyris cf. *tastubensis* Tschern. (found in Schwagerina Limestone of the Urals and in Indo-China),
Spirifer cf. *tibetanus* Dien.,
,, (*Neospirifer*) *fasciger* Keys. var. *paucicostulata* Reed (a Chitral variety),
Spiriferina (*Spiriferallina*) cf. *crestasta* Schloth, var., *fastigata* Schellw. (found in the Carnic Alps, Himalaya and Donetz basin),
Martiniopsis orientalis Tschern. (found in the Urals),
Martinia cf. *triquetra* Gemm. (found in the Urals and Indo-China),
Hemiptychina cf. *himalayensis* (Dav.), (found in the Salt Range, Chitichun and Kashmir),
Dielasma plica Kut. (found in the Urals, Indo-China, Shan States, and central Asia),
Athyris sp.
Orthothetes (*Schellwienella* ?) sp.,

Lamellibranchiata—

Pseudamusium tibeticum Reed,
Palaeolima aff. *dieneri* Frech.,
Edmondia cossoni Reed,

Gastropoda—

Euomphalus cf. *pusilliformis* Wanner. (species found in Timor)
Pleurotomaria ? sp.,
Bellerophon sp.,

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[1] H. H. Hayden. *Mem.* XXXVI, pt. 2, 27-22 (1907).
[2] H. H. Hayden. *Mem.* XXXIX, 52 (1911).
[3] *Pal. Ind.* New Ser. Vol. XIX (1931).

Cephalopoda—
  Nautilus sp.

This fauna has no general affinity with the Productus Limestone fauna of the Salt Range or with the Productus Shales and Zewan faunas of the Himalaya, and possesses no definitely Permian element. On the other hand, the brachiopods are almost without exception, forms known in the Upper Carboniferous of the Ural Mountains or in parts of central Asia; the prevalence of the widespread foraminifer *Schwagerina princeps* is also strongly suggestive of the Uralian.

The Dothak series of the Tibetan provinces of Tsang and Ü includes part at least of the Trias, but may extend down into Permian or even Carboniferous horizons.[1]

AFGHANISTAN.

Fusulina Limestone series.—In the neighbourhood of Ak Robat in Bamian the Helmad series, already described, bridges the gap between the Devonian Hajigak and a crinoidal limestone containing *Fusulina*. A continuous belt of this limestone also extends from the middle of the Ghorband valley to Ak Robat. It is for the most part a dark grey, more or less crystalline rock, with numerous veinlets of calcite. In the Ghorband valley it is unfossiliferous but between the Shibar Pass and Balula, and again in the mountains on the north side of the Bamian Valley, parts of the limestone are full of *Fusulina* and *Schwagerina*. With the limestone of this series are associated in places a thick bed of conglomerate and some thin bands of slate and quartzite[2].

The fossils, as determined by Dr. Cowper Reed, belong to one stratigraphical horizon and include the following[3].

Foraminifera—
  Fusulina elongata Shum. (4)
    ,, *uralica* Krot.,
    ,, cf. *verneuili* v. Möll.,
  Schwagerina princep Ehrenb. (including *Schw. verbeeki* Gein.),
    ,, (*Doliolina*) *lepida* Schwag. (Hayden's determination),
  Neoschwagerina craticulifera Schwag.,
  Cancellina primigena Hayden,
  Sumatrina annae Volz,

Actinozoa—
  Syringopora sp.,
  Tachylasima haydeni Reed,

Bryozoa—
  Polypora aff. *biarmica* Keys. ?

Brachiopoda—
  Productus (*Dictyoclostus?*) *afghanensis* Reed,
    ,, (*Dictyoclostus?*) *volgensis* Stuck. var. (probably identical with *P. acutauritus* Mansuy from Indo-China),
    ,, (*Dictyoclostus?*) *suborientalis* Reed,
    ,, (*Dictyoclostus?*) cf. *genuinus* Kut.,
    ,, *craticulatus* Reed,
    ,, (*Tschernyschiella*) *porrectus* Kut.,
    ,, (*Echinoconchus*) *fasciatus* Kut., var. *cristata* Reed,
    ,, (*Linoproductus*) *sinmensis* *Tshern.*,
    ,, (*Avonia*) *bamianus* *Reed*,

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[1] H. H. Hayden. *Mem.* XXXVI, pt. 2, 21-22 (1907).

[2] *Mem.* XXXIX, 52 (1911).

[3] *Pal. Ind.* New Ser., Vol. XIX (1931).

[4] Some, if not all of these farms figured by Hayden as *Fulsulina elongata* (*Rec.* XXXVIII, Pl. 20, figs., 1-12 (1909)) probably belong to the Permian species described by Kahler as *Polydiexodina persica* (See Professor A. Douglas, *Pal. Ind.* New Series, Vol. XXII, *Mem.* 6, 46 (1936).

Productus (*Krotovia*) *translatus* Reed,
,, (*Overtonia*) cf. *fimbriatus* Sow.,
Chonetes sp.
Derbyia aff. *grandis* Waag. ?
,, aff. *crassa* (Meck and Hayden),
Meekella aff. *striatocostata* (Cox),
Uncinuloides timorensis Beyr.,
Uncinunellina (?) *wangenheimi* Pander,
Pugnax cf. *swallowi* Shum.
Rhynchopora geinitziana (de Vern.),
,, *bumiana* Reed,
Camarophoria sella Kut., var. *transversalis* Reed,
Martinia cf. *triquetra* Cemm.,
Martiniopsis aff. *convexa* Tschern.,
Squamularia (*Neophricodothyris*) *asiatica* Chao., var. (probably identical with *S.* (*N.*) *baralensis* Reed, from the Lower Productus Limestone),
,, (*Neophricodothyris*) cf. *pulcherrima* Gemm. ? (probably equivalent to *S.* (*N.*) *nummulina* Reed, from the Middle Productus Limestone),
,, cf. *rostrata* (Kut.),
,, cf. *dieneri* (Schellw.).
Spiriferina reducta Reed.
Hemiptychina schellwieni Gort., var. *subcircularis* Reed,
,, *tridentata* Gort., var. *pluriplicata* Reed.
,, (*Beecheria*) cf. *sublaevis* Waag. ?
Notothyris turgida Reed.
Lamellibranchiata—
Pterinopecten bamianus Reed,
Plethomytilus (?) *plausibilis* Reed,
Leiopteria serotina Reed,
,, (*Angustella*) cf. *Praeangusta* (Frech).
Myalina sp.,
Gastropoda—
Capulus (*Pileopsis*) sp.
Cephalopoda—
Paraceltites bamianus Reed,

This fauna is distinct from that known in the Pamirs and Chitral; not only is the facies somewhat different but none of the species, with the exception of some of the Foraminifera, is common to these areas. It appears to have close relation with the Schwagerina Limestone of the Ural Mountains and there is some affinity with the Fusulina Limestone of the Eastern Alps, with the Gudalupian fauna of Texas, and with the Upper Carboniferous of Sumatra, Java, China and Japan. Nevertheless, its character as a whole is Permian, and to the Lower division of that system it should probably be assigned.

In Western Afghanistan, the Fusulina Limestone is exposed to the east of Herat, in the Doshakh range to the west of that town, and on the other side of the Hari Hud river. In this area, it was originally thought that the Talchir and other stages of the Gondwana were represented, but these identifications are extremely doubtful.[1]

Khingil Series.—On the north side of the high range separating Khurd Kabul from Butkhak, to the east of Kabul city, Hayden has mapped a limestone series under the name of Khingil which probably ranges from some horizon in the Productus Limestone to the Upper Trias. Fossils from the lower portion includes many small *Productus* and probably *Spirifer*, but the matrix proved too hard for their extraction. This provisional "Khingil series" caps and probably forms the greater part of the Khingil range on the east of the Kabul Plain, extending across the Lataband and the Kabul river and occupying most of the hills between the eastern edge of the Kabul plain and the Panjshir river. It covers an extensive area in eastern Afghanistan and probably continues through the Safed Koh to Chura and the Bazar Valley.[2]

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[1] H. H. Hayden. *Mem.* XXXIX, 33 (1911).
[2] *Mem.* XXXIX, Pt. 1, p. 22 (1911).

Doab Series—To a series exposed near the Doab-i-Mekh-i-Zarin or junction of the Kahmard and Saighan rivers in eastern Afghanistan, and composed mainly of volcanic ejectamenta and lava flows interbedded with shales and sandstones. Sir Henry Hayden gave the name of Doab. This series covers a large area in both upper and lower Saighan and in the former is seen to lie unconformably upon the Fusulina Limestone ; in most cases, it is covered with a well-marked discordance by the overlying plant-bearing Saighan series of Jurassic age. While the Saighan series appears to be entirely of fresh water origin, the Doab is partly marine and partly sub-aerial. Hayden thought that the unconformity between these two formations was of merely local importance, and that the Doab was more closely associated with the Saighan than with the underlying Fusulina Limestone and might be regarded as partly Triassic and partly Jurassic in age[1]. Dr. West, however, has recently proved that the unconformity between the Doab series and the Saighan series is far from trivial and must represent a considerable interval of time ; this conclusion provides an incentive to correlate the Doab series with the Panjal Volcanics of Kashmir.

The Doab beds comprise volcanic ashes, breccias and trap flows, some of which are amygdaloidal, interbedded with shale and sandstone, the shale occurring more usually in the upper horizons ; conglomerates are locally to be found, and in one locality a coarse volcanic agglomerate has been noted. The series is seamed with sills and dykes of igneous rock which, in the case of the dykes, cut right across the strata ; where these dykes extend up to the junction with the overlying Saighan beds, they are invariably seen to stop abruptly at the junction and never to penetrate the younger formation as Hayden supposed.

There is good evidence to show that the Doab rocks underwent considerable tilting, folding and denudation prior to the deposition of the Saighan beds. West remarks that "a characteristic feature of the highest beds of the Doab series is the presence of white and red beds which appear to represent a zone of weathering on the old land surface of those times. These brightly-coloured beds are seen in many places at the top of the Doab series, and particular mention may be made of their occurrence in the cliffs on the west side of the Darra Ishpushta, just south of the Ishpushta camp, from where they are clearly seen. Their formation appears to be quite independent of the nature of the topmost Doab rocks, affecting, for example, the intrusions of quartz porphyry as well as the sedimentary rocks ; sometimes, for example, on the west side of the Qol Hotapurak, the zone of colouring, while being parallel to the plane of junction of the two series, cuts across the bedding of the rocks of the Doab series."[2] These lightly-coloured beds do not belong to the base of the Saighan series, where they were placed by Hayden, but to the top of the Doab series.

PERSIA.

Grave doubt attaches to the specimens of *Glossopteris* reported to have been collected in the province of Khorassan, across the Persian frontier, especially, as these plant remains are said to have been associated with beds containing Jurassic marine fossils.[3]

A productid fauna from the Kuh-i-Gakhun is thought by Dr. J. A. Douglas to be of Upper Carboniferous age. A thick predominantly limestone formation found in Luristan, Bakhtiariland, Kuhgalu, and to a more limited extent in the Kuh-i- Gakhun, corresponds in some proportion to the Productus Limestone of the Salt Range in India. The most complete sequence is found in Bakhtiariland in the form of 2,000-3,000 feet of dark coloured limestones and dolomites with some carbonaceous shales. In the lower half of the succession, which is dark in colour, productids, fusulinids and corals are abundant. The upper, lighter-coloured half tends to be dolomitic or oolitic, and has been largely leached.

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[1] *Mem.* XXXIX, 29 (1911).

[2] Private Communication.

[3] C. L. Griesbach. *Rec.* XXI, 50 (886).

KHYBER AREA.

A Carboniferous or Permian limestone, with indistinct fossils and many fragments of crinoids, is reported in the Siah Koh, a well-defined part of the northern ranges of the Safed Koh, the rock is described as resembling the crinoid limestone of the Hindu Kush.[1] At the eastern end of the Bara valley, the Triassic shales and grits are faulted against blue schistose slates and highly altered limestone, the latter very similar to the limestone on Ghund Ghar, the hill overhanging the eastern mouth of the Khyber Pass.

The area between the Rohtas hill and the Bara valley is bounded on either side by rocks which have been described as Carboniferous forming in the main a syncline with Trias and possibly younger rocks between[2]. To the south, the Surghar hills consist of a hard, dark blue slate with bands and patches of white quartzite, all greatly indurated, dipping at high angles to the north and faulted against the Trias ; these rocks are similar to the rocks in the Khyber Pass. In an eastern prolongation of the Surghar hills, between Bara Fort and Jamrud, are hard, banded, flaggy and steeply dipping limestones, greatly altered, largely crystalline, and unfossiliferous, and identical with a rock overhanging the Khyber at Ghund Ghar and with much of the limestone of Rohtas hill, both of which occurrences are assigned to the Carboniferous. The Ghund Ghar rock, exposed on the south side of the entrance to the Pass, has, towards the summit, been locally altered by the intrusion of a green igneous rock to a fine, crystalline marble of considerable beauty ; this limestone is overlain by a band of highly ferruginous quartzite with beds of alum shale, the whole capped by grey limestones. The shale series has been classed as Upper Carboniferous to Permian ("Permo-carboniferous") ; its limestones include a crushed crinoidal limestone and a dense coaral limestone from the surface of which stand out the silicified remains of many corals and echinoderms. Near Walai are beds of massive, dark grey limestone and of a peculiar yellowish highly calcareous sandstone containing the remains of numerous brachiopods now largely replaced by bright red iron oxide. From a westward extension of the limestone near China were collected *Hustedia grandicosta* Waag., "*Rhynchonella*" *morahensis* Waag., *Camarophoria purdoni* Dav. and other fossils ; from blocks derived from the sandstone were obtained :

Productus (*Waagenoconcha*) *abichi* Waag.,
" " " " , var *serialis* Waag.,
Camarophoria pinguis Waag.,
" *purdoni* Dav.,
Rhynchonella morahensis Waag.,
Terebratuloidea minor Waag.,
Hustedia grandicosta Waag.,
Spiriferina cf. multiplicata Sow.,
Allorisma sp.

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[1] C. L. Griesbach, *Rec.* XXV, 71 (1892).

[2] H. H. Hayden. *Mem.* XXVIII, 109 (1898).

All these forms occur in the Productus Limestone of the Salt Range, and the horizon indicated is one between the Middle and Upper divisions and rather nearer the Middle. Since the sandstone is underlain by the limestone already mentioned, which above China village has a thickness of perhaps 400 feet, and is overlain by other limestones, it is not unlikely that the whole of the Productus Limestone series is represented.

Hayden's subdivision of the beds exposed between Ali Masjid and the Surghar range may be tentatively correlated as follows :—

4. Red and brown shales and grits of the southern side of the Bazar valley..	Trias
3. Limestones and calcareous sandstones with Productus Limestone fossils.	Permian
2. Brownish-green and reddish shales with flaggy quartzites and subordinate bands of limestone and dolomite.	
1. Altered limestones of Rohtas hill, Ghund Ghar and the Surghar range . (Older Palaeozoic)	? Carboniferous

At Shahidmena in the Mullagori tribal country of the Khyber Agency are quarries in a marble, which is the metamorphosed form of the limestone found at Ali Masjid, Rohtas and Ghund Ghar, and owes its marmorisation to dykes and sills of epidiorite. The relation of this pure white, saccharoidal marble, which is of extermely good quality, to the overlying schists and to the underlying schists with graphitic layers is not clear.[1] The strike is towards Jawaramena and Lowaramena ; to the south-west of the latter, the limestone forms high cliffs on each side of the Kambela Khwar, where again intrusions of epidiorite in dykes and sills have caused the same metamorphism. This rock, which supplies most of the marble exported from the Peshawar district, is also quarried at Maneri in the Swabi *tahsil*, where it is variously coloured, white, grey, green and yellow, the green variety being serpentinous with over 7 per cent. of silica. The marble of this area, according to Coulson, has been formed by the alteration of a dark-coloured limestone by numerous intrusive epidiorite dykes. Other occurrences probably of the same rock are reported in the hill-masses of Panjpir Ghar and Shah Mansur Ghar, at Ambar, and in the hill of Ghundai Tarako on the borders of Swat. In the last mentioned area, marmorisation has also been brought about by intrusions of epidiorite and amphibolite, and perhaps also by the biotite granite of Buner.[2] The white marble from Shahidmena and Maneri is a saccharoidal rock consisting of over 99 per cent. of pure calcium carbonate. The intrusive dykes and sills belong in all probability to the Panjal Trap suite.

PALAEOGEOGRAPHY OF THE LOWER AND MIDDLE CARBONIFEROUS EPOCHS.

The Lower and Middle Carboniferous, *i.e.*, the Dinantian and Moscovian, are exposed in the northwest Himalaya, but our knowledge thereof is scanty, as it is in most other parts of Gondwanaland, a result, as Dr. du Toit points out, of marine regression leading in some places to deposition of estuarine or continental sediments off the mainland, in others to exposure of the sea-floor.

The Lower is represented in Kashmir by the Syringothyris Limestone, belonging mostly perhaps to the Tournaisian stage, and in Spiti by the Lipak series which probably includes both Tournaisian and Viséan. Further work will no doubt discover more extensive exposures of the Lower Carboniferous along the Himalayan range, occupying the channel along which the Viséan fauna is thought to have travelled eastwards to the Chinese basin. In China and western North America, as well as in Russia, many thousands of square miles are occupied by Carboniferous strata in horizontal or gently undulating sheets. In China, the Lower Carboniferous consists largely of a brown bituminous limestone, the equivalent of the Carboniferous Limestone of Europe ; in it, and in the corresponding limestones of Russia on the one side and Japan and North America on the other, the foraminifer *Fusulina* plays a prominent role. Westwards, the open sea of the north Russian area in early Carboniferous times was replaced by a series of constricted gulf-like seas.

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[1] A. L. Coulson. *Rec.* 71, 332 (1936).

[2] A. L. Coulson. *Rec.* 72, 228 (1937).

The Carboniferous of Indo-China is mostly of Viséan age, and a Lower Carboniferous assemblage, showing a striking resemblance to the Culm of western Europe has been noted in Lower Siam in a rock resembling one found below the so-called "Carboniferous Limestone" in the Langkawi Islands of the Malaya States.[1] This "Carboniferous Limestone" of the Malay Peninsula has in places yielded a Viséan fauna.[2] Curiously enough, neither the Plateau Limestone of Upper Burma nor the Moulmein Limestone of Lower Burma has so far supplied either Lower, Middle or Upper Carboniferous fossils, with the doubtful exception of a *Spirifer*, but it is not improbable that a Viséan assemblage will one day be discovered at some level in that thick and largely unfossiliferous sequence ; only seventeen miles east of the Salween river, a Lower Carboniferous fauna has been obtained at Ta-li-shao on the western edge of the Yung-chang Fu plain and belongs, so far as the evidence goes, to the Viséan.[3] There is little doubt that the Carboniferous occurrences of Sumatra, Dutch Borneo, Malay, Indo-China and Burma, are all detached outcrops of one great system. The Viséan epoch witnessed an extensive marine transgression in northern Asia. On the other hand during the greater part of the Lower and Middle Carboniferous epochs, the western two-thirds of Australia persisted as land.

The Middle Carboniferous or Moscovian is poorly represented in Asia. Part of the Po series of Spiti and of the Fenestella Shales of Kashmir may belong to this group, though there is not complete agreement on the matter ; Grabau suggests that these formations include both Middle and Upper Carboniferous levels, while Gregory and Barrett refer them both to the Upper subdivision. The Middle Carboniferous in Europe was an epoch of warm moist climate even in arctic latitudes. The Moscovian in Asia and Europe was an epoch of shrinking seas and the accumulation of continental deposits, especially of coal, except in north-western Russia where a local marine transgression occurred : China for the most part was a land area with coal basins. The palaeogeography of Asia during the Upper Carboniferous and Permian will be considered in the chapter dealing with the Gondwana continent.

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[1] A. L. Coulson. *Rec.* 72, 221 (1937).

[2] Stanley Smith " Geology of Malaya ", 56 (1931).

[3] F. R. Cowper Reed. *Pal. Ind.* New Ser. Vol. X, *Mem.* 1, 24 (1927).

CHAPTER XXI.

EXTRA-PENINSULAR TRIAS.

Palæozoic-Mesozoic boundary. **The Salt Range and its trans-Indus continuation** : Distribution and classification ; Ceratite beds ; Kingriali Sandstone ; Kingriali Dolomite ; Stratigraphical position of the faunas. **Punjab and Central Himalaya** : Position ; Terminology ; Mode of occurrence ; Thickness and character ; Subdivision ; Lower Trias of Spiti and Garhwal ; Lower Trias of Byans ; Correlation of the Lower Trias ; Middle Trias ; Anisian of Spiti and Garhwal ; Anisian of Byans ; Correlation of the Himalayan Anisian ; Ladinian of Spiti ; Ladinian of Kumaon ; Relationships of the Himalayan Ladinian ; Upper Trias of Spiti and Garhwal ; Carnic of Spiti ; Carnic of Garhwal ; Upper Trias of Byans ; Correlation of Tropites Limestone ; Lower Noric of Spiti ; Lower Noric of Garhwal ; Middle Noric of Spiti and Garhwal ; Lower and Middle Noric of Byans ; Upper Noric. **Nepal. Exotic Blocks from Tibet. Southern Tibet. Mount Everest area. Sikkim. Kashmir ;** Vihi area ; Palgam outcrop; Islamabad belt ; Exposures east and west of the Wular Lake ; Sonamarg-Gurais belt ; Shamsh Abari syncline ; Zanskar basin ; Changchenmo valley ; Lingzi Thang ; Depsang plains, Karakoram Pass ; Baltistad ; Tosh Maiden-Gulmarg-Golabgah belt ; Outline on the southwestern flank of the Pir Panjal : Himalaya-Hazara syntaxis. **Hazara and Attock** : Hazara district ; Attock bistrict. **Chitral and the Pamirs. Afghanistan ;** Dóab series ; Khingil series. **Baluchistan. Burma** : Arkan Yoma ; Northern Shan States ; Karenni. **Burma-Siamese frontier. Yunnan** : Introduction ; Belt between Puerh Fu and the Mekong ; Belt between Ta-lu and Hsin-chuang ; Exposures east and south-east of Erh Hai.

Palaeozoic-Mesozoic boundary.—It is by its failures that the geological record has been classified, and only by the gaps therein is a clean subdivision rendered possible. Such gaps, however, can never be universal since it is impossible to believe that since Archæan times sedimentation ceased entirely over the whole surface of the globe for however short a period. A hiatus in one region is found to be filled in another and the boundaries of subdivisions applicable to the former become artificial when applied to the latter. The repeated discoveries of intermediate stages of passage beds make it more and more difficult to draw the dividing lines which are necessary for logical terminology. Examples of such difficulties have already been noted in this manual, and the Palæozoic-Mesozoic succession in India has in the past been quoted as an example. It is true that in most places the Permian in India is followed by the Lower Trias with no visible discordancy, and it was at one time a matter of dispute whether beds now referred to the latter should not be grouped with the Permian, but it is to-day recognised that the change in fauna between Upper Permian and Lower Trias is just as marked and abrupt in India as it is in Europe and other parts of the globe. The gap between the two systems has from time to time been partially bridged by discoveries of intermediate stages in the Alps and elsewhere, but, although there may be no angular unconformity, the advent of the Mesozoic marks in a general way a noticeable change in the forms of life, and this is as true in Asia as it is in the Western hemisphere. In northwest India only four of the Lower Triassic ammonite genera, *Medlicottia, Episageceras, Xenaspis* and *Xenodiscus,* are found in the Permian below. The extinction of the Productus Shales brachiopod fauna is as abrupt as the appearance and predominance of the Triassic cephalopods although this may have been largely due to changes in salinity, temperature, the direction of sea-current or food-supply. The Permian of India, even in the upper of its three divisions, shows closer faunal affinities with the Upper Carboniferous than it does with the Trias. The want of visible unconformity between the beds of the two systems, in any case does not preclude a disconformity or hiatus in deposition, indicating a temporary withdrawal of the sea during an appreciable time interval.

In the Peninsular region of India, the Trias forms part of the Gondwana succession which will be considered in the next chapter. Outside the Peninsula, it has been recognised in the western half of the Himalaya and its trans-Jhelum continuation in Hazara and Attock, in southern Tibet, in the Salt Range of the Punjab, and its Trans-Indus continuation in Chitral and the Pamirs, in Afghanistan and Baluchistan, and finally in the Arakan Yoma, the Shan States and the Siamese frontier of Burma.

THE SALT RANGE AND ITS TRANS-INDUS CONTINUATION.

Distribution and Classification.—In the Salt Range of the Punjab, immediately succeeding the Productus Limestone, and having the same lithological aspect, are the Ceratite beds of Lower Triassic age. Gee's work shows that the break in deposition is far greater between the Trias and the Jurassic than it is between the Permian and the Trias. Wherever the basal beds of the Trias are seen, they rest with no visible discordance upon the Upper Productus beds ; the junction, however is described as distinct and the basal Ceratite limestone as very characteristic and it is possible that a time interval may separate the deposition of the topmost Productus beds from that of the overlying Ceratite beds, in spite of the absence of any signs of unconformity or transgression. The time interval between them in fact may have been considerable, for not a single species bridges the two copious faunas, and the lowest stage of the Trias—the Otoceras zone—appears to be entirely unrepresented.

The Ceratite beds of the Salt Range Trias first make their appearance above the Upper Productus limestones north of Kund, and thicken rapidly westwards. At first they are overlain by a Palaeocene lateritic deposit or an equivalent thereof, but to the south of Uchhali some grey and variegated sandstones and shales, probably of Jurassic age, intervene between the Ceratite beds and the Palaeocene. Further along the range, to the southwest of Sakesar, between these presumed Jurassic strata and the Ceratite beds there appears a massive sandstone stage below and a stage consisting of thin limestones, dolomites and calcareous sandstones above. These two stages, which Mr. Gee has named respectively the Kingriali Sandstone and the Kingriali Dolomites, contain only a few poorly preserved fossils but, on stratigraphical grounds, are linked with the underlying Ceratite beds as part of the Triassic sequence. These two stages were so grouped by Waagen in 1895 ; they are well represented in the western end of the Salt Range, are seen again at Kalabagh and in several other sections of the Maidan range across the Indus, and form prominent outcrops in the Khasor range as well as in the Shekh Budin area of the Marwat range behind. Wynne seems to have hesitated between allotting these two stages to the Trias or to the Jurassic, but Gee has traced a marked overlap occurring above them and, chiefly for this reason, includes them in the Trias, thus :—

Mianwali series .	3. Kingriali Dolomites—maximum thickness in the Salt Range,	240 feet.
	2. Kingriali Sandstones—maximum thickness in the Salt Range,	220 ,,
	1. Ceratite Beds—maximum thickness in the Salt Range,	440 ,,
		900 feet

The Mianwali series, as Gee has named the whole formation, probably reaches its maximum development of at least 950 feet in the southern part of the Khasor range and in the southern slopes of Shekh Budin hill. The various members of the series are mutually conformable ; according to Wynne, there is frequent variation in detail, but Gee describes the sequence of sedimentation as steady, though of varying type during the successive stages.[1] The formation is probably for the most part shallow water, marine in character, though local fresh-water or estuarine conditions have left behind a number of plant impressions in the flaggy sandstones and sandy shales near the top of the Ceratite stage. It is probably this horizon which has yielded remains of a pteridospermatous microsporophyll with clustered pendulous sporangia and named by R. V. Sitholey *Indotheca sakesarensis*.

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[1] Written communication.

Ceratite Beds.—In the Ceratite Beds Waagen claims to have found the following general succession, which, however, is not always clearly indicated in Gee's sections :—

Ceratite Stage	Upper Ceratite Limestones.	
	Ceratite Sandstones	Upper Middle, or Stachella beds Lower
	Ceratite Marls.	
	Lower Ceratite Limestone.	

It is the Lower Ceratite Limestone which is the first member of the Trias to make its appearance north of Kund, consisting of from 5 to 10 feet of grey flaggy beds with *Ceratites* and about 25 feet of olive-green shales. Westwards and northwestwards higher *Ceratite*-bearing shales, marls and flaggy sandstones make their appearance in the upper slopes and in the folds at the top of the range, and frequently in the form of outliers cap the irregular plateaus of Productus Limestone. From north of Kund to the western end of the range, the Ceratite stage extends continuously except where interrupted by dislocation ; it is well exposed near Chhidru, and in the western scarp overlooking the Musa Khel plain occupies a regular position in the form of a thin band between the Productus Limestone below and the Jurassic above. On the other side of the Indus, the Ceratite beds always accompany the Productus Limestone. In the Maidan range, at the southwestern end of the Khasor range, and in the Shekh Budin area near the southwestern end of the Marwat range, this stage is succeeded by the Jurassic ; throughout most of the Khasor range it is overlain by Siwalik beds.[1]

A more or less complete section of the stage is seen to the northeast of Warcha Mandi in the cis-Indus Salt Range, where it includes the Lower Ceratite Limestone, 8-10 feet thick, followed by about 200 feet of olive-green ceratite bearing shales and marls with bands of greenish grey flaggy sandstones, which are in turn capped by 5-8 feet of the flaggy Upper Ceratite Limestones containing *Ceratites*, *Stachslla*, and other fossils. This gives a total thickness of nearly 220 feet, but the addition of about 75 feet of doubtful overlying beds, comprising a shelly calcareous sandstone and some brown, red and grey selenite-bearing sandstones and ferruginous shales, would bring it up to nearly 300 feet. In other sections the following thicknesses have been observed : in the spur west of Sarai, 435 feet ; in the Nammal gorge, 420 feet; in the gorge southeast of Daud Khel, 290 feet; below Kingriali in the Khasor range, about 600 feet. Some of the limestones of the Ceratite stage are magnesian, others contain glauconite.

The following fossils have been identified by Waagen (revision by Dr. Spath in square brackets).[2] It will be noted that most of them are new species, many of which are founded on single specimens or fragments, and that with few exceptions each form is restricted to a single stage. The poor stage of preservation of the fossils is perhaps partly responsible for their multiplicity.[1]

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[1] A. B. Wynne. *Mem.* XVII, 240 (1880).

[2] *Pal. Ind.* Ser. XIII, Vol. II, (1895). Mr. Gee's collections of Triassic fossils from the Salt Range and trans-Indus ranges are, it is understood, under examination by Dr. L. F. Spath. From the Lower Trias of the Warcha area, Reed, Cotter and Lahiri record *Pseudosageceras multilobatum* Noetl., *Flemingites* sp., "*Meekoceras*" (*Koninckites*) sp., "*Aspidites*" [*Clypeoceras*] sp. and *Ophiceras* sp., in flaggy limestones above the Upper *Bellerophon* bed (*Rec.* LXII, 442 (1929). From the Lower Trias of the Salt Range, apparently including the Lower Ceratite Limestone, the Ceratite Marls and the Ceratite Sandstone, Vredonburg identified seven additional forms : "*Celtites*" [*Anakashmirites*] *radiosus* Koken, "C" [*Anak.*] *fortis* Kok., "*C*" [*Anak.*] *fallex* Kok., [*Xenodiscoides*] *perplicatus* Frech, *Hedenstroemia mojsisovicsi* Dien. (*? Anahedenstroemia himalayica* Spath) ; see *Cat. Foss. Ceph. Brit. Mus.*, Pt. IV, 217 (1934), *Pseudosageceras multilobatum* Noetl. and "*Aspidites*" (*Clypeoceras*) *superbus*, var. *praecursor* Frech (*Paraspidites praecursor*) (*Rec.* XLI, 59 (1911))

From the thin Lower Ceratite Limestone were obtained :—

Cephalopoda—
"*Dinarites*" [*? Prionites*] *patella* Waag.,
Ambites rupestris Waag.,
Propiychites oldhamianus Waag.,
,, *discoides* Waag.,
"*Meekoceras*" *varians* Waag.[2]
Koninckites vestus Waag.,
,, [*Prtonolobus*] *impressus* Waag.,
,, *davidsonianus* (de Kon.),
"*Lecanites*" [*Gyraphiceras*] *gangeticus* de Kon. (horizon not quite certain),
, [*? Gyronites*] *psilogyrus* Wagg.,
[*Prionolobus*] *undatus* Waag. (from Kafir Kot as well as from cis-Indus localities),
,, [*Gyrolecanites*] *impressus* Waag.,
Gyronites frequens Waag.,
,, *superior* Waag.,
,, [*?*] *nangaensis* Waag.,
,, [*Glyptophiceras*] *plicosus* Waag.,
Prinolobus atavus Waag. (from Kafir Kot, as well as from cis-Indus localities).,
,, *compressus* Waag.,
,, *plicatus* Waag.,
,, *ovalis* Waag.,
,, *buchianus* de Kon.,
,, *plicatilis* Waag. (from Shekh Budin only),
,, *ophioneus* Waag.,
Kymatites typus Waag (?="*Meekoceras*" cf. *radiosum* Waag.; from the Shekh Budin area only).

Pisces—
Colobodus damesi Waag.,
Gyrolepis sp.,
Acrodus flemingianus de Kon. (horizon not quite certain).

The next stage is a thick, marly zone, which yields readily to weathering turning to a light greenish colour; from these Ceratite marls come the cephalopods.[3]

"*Dinarites*" *minutus* Waag. [? *Xenoceltites spitsbergensis* Spath],
Clypites typicus Waag.,
,, *kingianus* Waag.,
,, *evolvens* Waag. [*Clypeoceras excentricum* Spath].
Ambites discus Waag,
,, *magnumbilicatus* Waag. (probably indistinguishable from *A. discus*),

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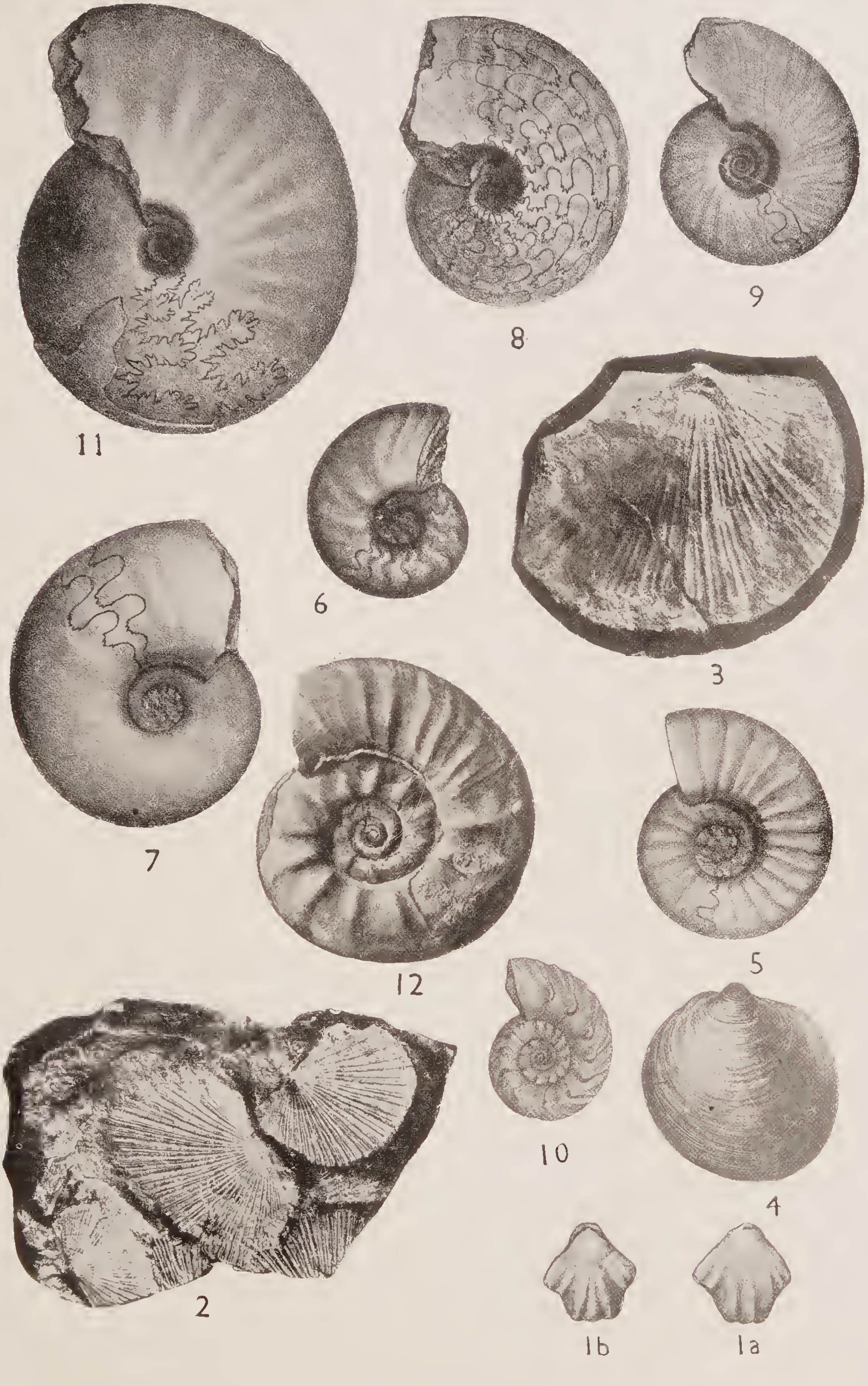
[1] According to Mr. Vredenburg, many of the species established by Waagen represent different modes of preservation of one and the same form, especially in the case of species and genera founded on the supposed absence of denticulations along the suture lobes, *Rec.* XLI, 59 (1911).

[2] According to Dr L. F. Spath, the genus *Meekoceras, sensu stricto*, does not occur in India.

[3] From the topmost yellow limestones of the Shekh Budin area, a horizon seen elsewhere to occur above the Dolomitie stage and below the plant-bearing Jurassic beds, a *Tropites*-like cephalopod is said to have been obtained. To it was given the name of *Pseudoharpoceras spiniger* (Verch.) *Rec.* XXV. 185 (1892); *Pal. Ind.* Ser. XIII, Vol. II, Pt. 1, 131 (1895); and due to its presence was the assignment of the two uppermost stages of Waagen to the Keuper. Dr. Spath believes this cephalopod to be an Upper Lias ammonite, a hildoceratid, and suggests that it may have been a loose form picked up from the surface (private communication).



TRIASSIC FAUNA.

1. *Rhynchonella trinodosi* Bittn. 2. *Daonella lommeli* Wissm. 3. *Monotis salinaria* Schloth. 4. *Pseudomonotis griesbachi* Bittn. 5. *Celtites multiplicatus* Waag. 6. *Ceratites wynnei* Waag. 7. *Meekoceras koninckianum* Waag. 8. *Otoceras clivei* Dien. 9. *Ophiceras sakuntala* Dien. 10. *Sibirites prahlada* Dien. 11. *Ptychites cognatus* Oppel. 12. *Xenodiscus himalayanus* Griesb.

G. S. I., Calcutta.

Proptychites lawrencianus de Kon. (from the base),
,, *latifimbriatus* de Kon.,
,, *ammonoides* Waag. (from the base),
,, *magnumbilicatus* Waag. (from the upper parts),
,, *khuensis* ("*choorensis*") Waag. (from the base),
,, *trilobatus* Waag. (from the upper parts),
,, (*? Eoptychites*) *undatus* Waag.,
Kingites lens Waag.,
,, *declivis* Waag.,
"*Meekoceras*" *koninckianum* Waag.,
,, *pulchrum* Waag. (*Paranorites* cf. *pulchrum*),
Koninckites ovalis Waag.,
,, [*Paranorites*] *volutus* Waag.,
"*Koninckites*" (*Paranorites*) *vercherei* Waag.,
Gyronites evolvens Waag. (horizon not quite certain),
Prionolobus rotundatus Waag.,
"*Prionolobus*" *undatus* Waag.,

In the lower portion of the grey Ceratite Sandstone occur :

Cephalopoda—
"*Ceratites*" *normalis* Waag.,
Prionites arcuarius Waag.,
"*Celtites*" *subrectangularis* Waag.,
,, *laevigatus* Waag.,
Kymatites posterus Waag.,
Kingites minutus Waag.,
"*Meekoceras*" *radiosum* Waag. [possibly identical with *Kymatites typus* Waag.],
Koninckites (*Paranorites*) *gigas* Waag. (horizon not quite certain),
lyellianus de Kon. (horizon not quite certain,)
"*Gyronites*" (*Xenodiscoides*) *rotula* Waag.,
" ,, " *radians* Waag.,
" ,, " *arenosus* Waag.,
" ,, " *vermiformis* Waag. [*Gyrophiceras vermiforme*].

From the middle Sandstone or Stachella beds come following :—

Cephalopoda—
" *Dinarites*" *coronatus* Waag., [perhaps a young *Kashmirites*],
" *Celtites* " *subrectangularis* Waag.,
,, *acutiplicatus* Waag.,
Paranorites ambiensis Waag.,
Proptychites [*? Eoptychites*] *plicatus* Waag.,
,, [*Eoptychites*] *obliqueplicatus* Waag.,
Flemingites glaver Waag.,
,, *nanus* Waag.,
,, *rotula* Waag.,
,, *radiatus* Waag.,
Parakymatites discoides Waag.,
" *Aspidites* " *arcuosus* Waag.,
,, [*Paranorites*] *magnumbilicatus* Waag.,
,, [*Paranorites*] *kingianus* Waag.,
,, *dentosus* Waag.,
,, [*Clypeoceras*] *discus* Waag.,
" *Meekoceras* " [*Xenodiscoides*] *falcatum* Waag.,
,, [*Paranorites*] *magnumbilicatum* Waag.,
,, *rotum* Waag.,
,, [*? Prionolobus*] *planulatum* de Kon.,
Koninckites radiatus Waag.,

Pisces—
Acrodus jaekeli Waag.

From the Upper Ceratite Sandstone comes the following cephalopod fauna resembling one observed in southern China [1].

" *Dinarites* " [*? Xenoceltites*] *evolutus* Waag.,
" *Ceratites* " *wynnei* Waag.,
Prionites trapezoidalis Waag.,

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[1] C. C. Tien. *Pal. Sin*, B, XV, Fasc. 1, (1933).

"*Celtites*" [*Kashmirites*] *armatus* Waag.,
Acrochordiceras [*Parastephanites*] *atavum* Waag.,
Proptychites (?) *aberans* Waag.,
Flemingites trilobatus Waag.,
,, *flemingianus* (de Kon.),
,, *compressus* Waag.,
"*Aspidites*" [*Clypeoceras*] *superbus* Waag. (horizon doubtful),
,, *evolvens* Waag. (probably including *Clypeoceras excentricum* Spath).
"*Lecanites*" *ophioneus* Waag.,

From the flaggy Upper Ceratite Limestone come the following cephalopods :

Prionolobus sequens Waag.
"*Dinarites*" *dimorphus* Waag.,
"*Ceratites*" *inflatus* Waag.,
,, *disculus* Waag.,
,, *murchisonianus* Waag.,
,, *angularis* Waag.,
,, *dimorphus* Waag.,
,, *sagitta* Waag.,
,, *patella* Waag.,
Prionites tuberculatus Waag.,
,, *undatus* Waag.,
,, *linguatus* Waag.,
"*Balatonites*" *punjabiensis* Waag. (possibly from a slightly lower horizon),
"*Celtites*" *trapezoidalis* Waag.,
,, [*Pseudoceltites*] *multiplicatus* Waag.,
,, *dimorphus* Waag.,
,, *acutiplicatus* Waag.,
,, *ovalis* Waag.,
,, *teres* Waag.,
Acrochordiceras dimidiatu Waag.,
,, [*? Stephanites*] *distractum* Waag.,
,, *coronatum* Waag.,
,, [*Silesiacrochordiceras*] cf. *damesi* Noetl.,
,, *compressum* Waag.,
Stephanites superbus Waag.,
,, *corona* Waag.,
Sibirites [*Anasibirites*] *kingianus* Waag.,
,, *chidruensis* Waag.,
,, *dichotomus* Waag.,
,, *inæquicostatus* Waag.,
,, *ceratitoides* Waag.,
,, *discoides* Waag.,
,, *angulosus* Waag.,
,, *parvumbilicatus* Waag.,
,, *ibex* Waag.,
,, *hircinus* Waag.,
,, *tenuistriatus* Waag.,
"*Coniodiscus*" [*Hemiprionites*] *typus* Waag.,
Monophyllites sp.,
"*Meekoceras*" *fulguratum* Waag.,
,, *tardum* Waag.,
"*Lecanites*" *convolutus* Waag.

Kingriali Sandstone.—The Upper Ceratite Limestone stage passes up into the Kingriali Sandstone, which consists largely of massive, white, grey or variegated, friable sandstone, current-bedded and sometime ripple-marked ; ferruginous bands of shaly sandstone and shale make up the rest of the stage. Southwest of Sakesar the Kingriali Sandstone is about 170 feet thick, in the Nammal gorge 180 feet, and southeast of Daud Khel in the extreme west of the range 105 feet. Across the Indus it is seen above Kalabagh and at several localities in the Maidan range, more regular exposures are seen in the Khasor range, and below Kingriali the stage is about 200 feet thick.

Kingriali Dolomite.—The Kingriali Sandstone passes up gradually into the Kingriali Dolomite stage, which makes its appearance beneath the Variegated stage of the Jurassic in the area west and northwest of Sakesar, thickening rapidly to 220 feet in the Nammal gorge. The upper junction with the Jurassic is sharp.

From what Dr. Waagen calls the " Bivalve Beds ", come the following cephalopods :—

"*Dinarites*" *sinuatus* Waag.,
"*Celtites*" *acutiplicatus* Waag.,
"*Lecanites*" *planorbis* Waag. (perhaps a worn example of *Gyronites vermiformis*),
,, *laqueus* Waag.

With these were found species of *Orthoceras* and *Bellerophon*,[1] and the bivalves which predominate in the stage—*Cardinia*, *Anoplophora*, *Gervillia* and *Rhynchonella*. These beds are recorded as occurring between the Upper Ceratite Limestone and Waagen's " Dolomitic beds ", and have probably been included by Gee in the base of his Kingriali Dolomite stage.

The Kingriali Dolomite stage where fully developed, comprises yellowish and grey dolomitic limestones and calcareous or dolomitic sandstones, with a few thin bands of shale. Some of the hard, splintery dolomites have a brecciated appearance and show " honey comb " weathering. About 220 feet of this stage are exposed in the Nammal gorge. It is well represented in the Tredian hills, and at south-east of Daud Khel, a thickness of 245 feet has been measured. Across the Indus the impure dolomites crop out in prominent cliffs a little north of Kalabag and recur at several other localities in the Maidan range. They are conspicuous in sections of the Khasor range and are especially well seen capping the Kingriali cliffs, where they are several hundred feet in thickness. At Shekh Budin, Wynne estimated the thickness to be between 200 and 300 feet. Waagen subdivided this stage into a lower Dolomitic sub-stage, with indistinct bedding, and an upper sub-stage of thinly-bedded and yellowish limestones. From the lower of these two small sub-divisions he records some small internal casts of indeterminable bivalves and gastropods ; the uppermost limestones are described as crowded with indeterminable fossils, chiefly bivalve shells but including some cephalopods.

Stratigraphical position of the faunas.—A peculiar feature of the Salt Range Triassic faunas is the abundance of ammonites, the rarity of goniatitic sutural lines, and the great predominance of ceratite sutural line. There appears to be no grounds for assigning any of the Salt Range stages to horizons above the top of the Lower Trias. Dr. Spath's classification is as follows, his " Eo-Tries " corresponding to the " Lower Trias " of this manual [2]:—

	Stratigraphical divisions.	Zones.	Salt Range representatives.
Upper Eo-trias	Prehungaritan.		
	Columbitan.	*Anasibrites.* *Owenites.* *Pseudosageceras.*	Upper Ceratite Limestone
	Owenitan.		
Lower Eo-trias	Flemingitan.	*Flemingites flemingianus.*	Ceratite Sandstone.
		Koninckites colutus.	Upper Ceratite Marl.
	Gyronitan.	"*Celtites*" *fallax.*	Middle Ceratite Marl.
		Prionolobus rotundatus.	Lower Ceratite Marl.
		"*Celtites*" *radiosus.*	Lower Ceratite Limestone.
	Otoceratan.		

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[1] Presumably the " *Nautilus* " of Waagen, *Rec.* XXV, 184 (1892). *Bellerophon* horizon is recorded by Reed, Cotter and Lahiri in the Productus Limestone of the Warcha area, the upper occurring immediately below the Triassic Ceratite beds.

[2] *Cat. Foss. Ceph. Brit. Mus.*, Pt. IV, 27 (1934)

THE PUNJAB AND CENTRAL HIMALAYA.

Position.—Under the heading of the Punjab and Central Himalaya will be considered occurrences of the Trias extending from the northeastern portion of the Kangra district of the Punjab, including the Spiti valley, through Bashahr State, Tehri Garhwal and the Kumaon division of the United Provinces, to the frontier of Nepal.[1] That part of the Kumaon division with which we are at present concerned comprises the district of Garhwal—often spoken of as British Garhwal—and the central belt of the Almora district formerly included under the terms Johar district and Byans district ; the northern part of British Garhwal is known as the Painkhanda pargannah and lies behind, *i.e.*, to the north of the great chain of snowy mountains.

The possibility of the upper part of the Krol series (Upper Krol Limestone) belonging to the upper side of the Permian-Trias boundary has already been mentioned in the last chapter, in which the Krol series has been described. Somewhere between the Shali series, which may represent the Krol formation north of Simla, and the Subathus (Eocene-Oligocene) come the Madhan Slates, whose precise age is an unsolved problem. They are briefly described in a later chapter.

Terminology.—The dark Productus Shales (Permian) of the western and central Himalaya are succeeded conformably by the Trias, the basal zone of which has a few fossils with Permian affinites. Both these systems form part of the broad sedimentary belt which stretches from Kashmir through Kangra, Bashahr, Tehri Garhwal and Kumaon to Nepal. The Lower and Middle Trias were formerly grouped under the term Lilang series, while the Upper Trias forms the lower portion of a great limestone sequence, over 2,000 feet thick in Spiti, which was separated by Stoliczka into two divisions, the Para below characterised by *Megalodon*, and the Tagling above. Sir Henry Hayden, however, has pointed out that there are no means of dividing this limestone in the field and has proposed the term Kioto, for what is a single stratigraphical unit, divisible only on a palaeontological basis, striding from the top of the Lilang quartzites to the base of the Spiti Shales.[2] Work in the Attock district, west of the Indus, shows the Kioto as a continuous limestone sequence, ranging probably from the base of the Upper Trias through the Rhaetic into the Lias ; possibly it has in places been mistakenly made to include a subdivision of the Cretaceous known elsewhere as the Giumal Sandstone. The limits of the Kioto limestone, therefore, are somewhat indefinite, but the term is useful when referring to older surveys whose results have not yet been brought into line with the classification of more intimately studied areas. The Kioto limestone is overlain by the Spiti Shales (Argovian to Valanginian), not only in the Himalaya of Byans, Painkhanda, Spiti and Kashmir, but also in the Hazara and Attock districts west of the Indus.

Mode of occurence.—Along this belt of the Himalaya, therefore, the beds of the Trias, Rhaetic and Lias appear to pass up one into the other, and to form a continuous sequence. The rocks to be considered in this section are the Himalayan facies of the Trias, whose lower limit is now readily defined, whose upper limit ends in the middle of this thick limestone sequence and can only be recognised by fossil evidence. From Kashmir to Nepal the Trias is a marine facies, consisting of a great development of limestones, dolomites and shales. Its rocks share largely in the mountain structure of the chain and occupy much of the high country in north Kangra and the flanks of the Spiti valley, and nearly the whole of the watershed range between Hundes and the Bhot Mahals of Garhwal and Kumaon.[1] East of Kashmir, the Himalayan Trias is without igneous rocks. Its distribution follows closely that of the Palaeozoic, in the synclines of which the Mesozoic sediments occur typically in long narrow strips, especially in Kumaon and can often be recognised from a distance by their rusty brown weathering. Good exposures are seen at Shalshal and Bambanag in Painkhanda, in the vicinity of the sources of the Lissar and Dhauli Ganga rivers where they form part of two enormous synclines, and in the Hop Gadh of the Kamet area ; for some twenty miles or more east of the Dhauli, exposures are limited to the Lower division of the system. In several places an apparently complete sequence from the Permian Productus Shales to the top of the Spiti Shales (lowest Cretaceous) can be observed on a single mountain side.

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[1] The grave confusion into which the literature of the Himalayan Triassic faunas had fallen was conscientiously rectified by Dr. Carl Diener, whose corrections should be gratefully remembered. Further amendations kindly made by Dr. L. F. Spath with regard to the Lower Trias have brought the corresponding portion of this chapter into line with the classification recently adopted elsewhere.

[2] At one time known as the "Gray Limestone."

Thickness and character.—The total thickness of about 4,000 feet quoted by Griesbach with respect to the Niti sections of Garhwal probably applies to the Lower and Middle Trias and the whole of the Kioto Limestone, and may be greater than this further to the west in Spiti, but only about half of this total belongs to the Trias. The lithological character of the subdivisions of the latter in most parts of this particular belt is remarkably uniform ; in the Lower Trias especially hardly any variation is perceptible. The formation as a whole is described as strikingly reminiscent of the Alpine Trias. The limestones are usually well bedded and, along some horizons, either concretionary or dolomitic. In most sections there is a notable contrast between the dark-coloured shales and limestones of the lower portion of the system and the light grey dolomitic limestones of the upper portion. The Kioto Limestone, including in its lower portion the Upper Trias, generally gives rise to precipitous inaccessible scarps, usually facing towards the south ; these have been described as the scarps of the Tibetan plateau, but the structural inter-relationship is not quite so simple. Within the Tibetan boundary to the northeast is a different facies of the system, represented by exotic blocks, which will receive separate attention.

The sequence throughout is concordant and there are no visible unconformities. Faunistic gaps occur, though some of these are probably filled by unfossiliferous beds—beds in which organic remains originally present have been subsequently obliterated or have so far escaped detection in a very inaccessible region. The Owenitan, for instance, has not been recognised in either Spiti or Painkhanda but may be represented in the former area by 24 feet of unfossiliferous shaly limestones and shales. The topmost zones of the Lower Trias, also, seem to be represented in both areas by the unfossiliferous Niti Limestone. Other missing horizons, such as the "*binodosus* zone" of the Anisian may eventually be found. Nonetheless one of the characteristic features of the Himalayan Trias seems to have been capricious sedimentation.

Subdivision.—The Himalayan succession of the Triassic system has been reviewed by Dr. Carl Diener, whose scheme of subdivision [2] forms the foundation of the attached table, in which revision regarding the European correlation of the Lower Trias have been made by Dr. L. F. Spath.

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[1] C. L. Griesbach. *Mem.* XXIII, 67 (1891).

[2] *Mem.* XXXVI, Pt. 3, 141-142 (1912).

HIMALAYAN TRIAS.

Alpine stages			SPITI	Thickness (in feet).	PAINKHANDA.	Thickness (in feet).	BYANS	Thickness (in feet).
Upper Trias.	Noric.	Upper .	Megalodon Limestone . . .	? 300	Megalodon Limestone . . .	? 300	Megalodon Limestone .	?
		Middle .	Quartzite Beds (*Athyris maniensis*) .	300	Quarizite Beds (*Athyris maniensis*).	250	Greenish black shales with sandy bands . .	1,000
			Monotis Beds	300	Liver-coloured limestones with *Anodontophora griesbachi* and *Sagenites* sp.	130-160		
			"Coral Limestone" and Plant Beds .	100	Limestone with *Spiriferina griesbachi*	320		
		Lower .	Juvavites Beds	500	Halorites Beds. . . . . Nodular Limestone with *Proclydonautilus griesbachi* . . .	200 70-100	Tropites Limestone.	80
	Carnic.	Upper .	Dolomitic Limestone . . .	300	Beds with *Halobia comata* . .	650-800	Gray Massive Limestone.	170
			Tropites Beds (*Tropites subbullatus*) .	600				
		Middle .	Zone of brachiopods and bivalves . Zone of *Joannites cymbiformis* and *Carnites floridus*	500				
		Lower .	Halobia Limestone	150	Brachiopod and bivalve bed. Traumatocrinus Limestone.	25		
			Daonella Limestone . . .	65				

HIMALAYAN TRIAS—*contd.*

Alpine stages				SPITI.	Thickness (in feet).	PAINKHANDA.	Thickness (in feet.)	BYANS.	Thickness (in feet.)
Upper Trias.				Daonella Limestone . . .	50	A thin passage limestone .	10-20		
Middle Trias.	Ladinian.	Upper	*Archelaus* zone.	Daonella Shales	160				
		Lower	*Reitzi* zone.	Passage beds at Kaga and Much .				Grey Massive Limestone. Zone of *Paraceratites thuillieri.*	130
	Anisen.	Upper	*Trinodosus* zone.	Trinodosus Limestone . . .	24	Trinodosus Limestone . .	20		
			Binodosus zone.						
		Lower		Beds with *Spiriferina stracheyi* and *Durgaites dieneri.*	6	Beds with *Spiriferina stracheyi* and *Durgaites dieneri.*	4	Zone of *Spiriferina stracheyi.*	

HIMALAYAN TRIAS—*contd.*

	Alpine stages.	SPITI.	Thickness. (in feet).	PAINKHANDA.	Thickness (in feet).	BYANS.		Thickness (in feet).
Middle Trias								
Lower Trias.	Prohungaritan . .	Nodular Limestone . . .	50-60	Niti Limestone . . .		Grey Massive Limestone.	Zone of *Rhynchonella griesbachi.*	50
	Columbitan . .	Shales with *Rhynchonella griesbachi* *Pseudomonotis himaica.*	3 3	Shales with *Rhynchonella griesbachi* *Pseudomonotis himaica.*	3	Chocolate Limestone.	Zone of *Sibirites spiniger.*	150
	Owenitan . .							
	Flemingitan, Upper and Middle Gyronitan .	Hedenstrœmisa Beds (*Flemingites rohilla*)	35½	Limestones and shales with *Flemingites rohilla ?* Hedenstrœmia Beds (fossils indeterminable) . .	30			
	Lower Gyronitan .	"Meekoceras" Beds . . .		"Meekoceras', Beds				
	Otoceratan . .	Otoceratan { Probably the same three zones as those in Painkhanda .	6½	Otoceratan { 3. Zone of *Ophiceras tibeticum* . . 2. Zone of *Episageceras dalailamae* . . 1. Zone of *Otoceras woodwardi* . .	21½	Passage Beds.		
	(Permian.)	(Productus Shales.)		(Productus Shales.)		(Productus Shales.)		

Lower Trias of Spiti and Garhwal.—The Lower Trias thickens eastwards from 40 feet in Spiti to about 50 feet in the Painkhanda area of Garhwal and 150 feet in Byans, but the most complete section is to be seen in the first of these localities. Although so thin, the Lower Trias is remarkably persistent and the sections in Spiti and Garhwal, although a hundred and thirty miles apart, show the same detail in lithology and fauna. Good exposures are present near Lilang, and still better ones to the southeast of Muth where its division into a lower and an upper stage is well displayed ; the dividing horizon is composed of some grey shaly limestones and shales which are poor in or devoid of fossils and mark a lithological change. The lower stage comprises dark crumbling shales, closely resembling the Productus Shales below, and alternating with hard black limestones weathering to a rusty brown. The alternations of limestone and shale are very regular and average from about 4 to 6 inches in thickness ; they are often much crushed into the subjacent shales by flexuring. The lower passes up through the practically unfossiliferous dividing horizon into the upper stage, in which the limestones predominate over the shales and become gradually less dark in colour.

The lower stage can be divided into two sub-stages, (*a*) the Otoceras Beds below, and (*b*) the "Meekoceras" Beds above.

The clearest section of the Otoceras Beds, or Otoceratan, is to be seen in the Shalshal cliff of Painkhanda, where it can be divided into three zones :

3. Zone of *Ophiceras tibeticum*.
2. ,, ,, *Episageceras dalailamae*.
1. ,, ,, *Otoceras woodwardi*.

Zone 1, the main horizon of *Otoceras woodwardi* and *Lytophiceras sakuntala* consists of a dark blue limestone which, near the top, is rich in *Pseudomonotis* (*Claraia*) *griesbachi*. Zone 2, a hard, dark clay with limestone concretions, contains very few fossils, the only two cephalopods among which are *Episageceras dalailamae* and *Proptychites scheibleri*. Zone 3, another dark blue limestone, is characterised by *Ophiceras tibeticum*. In Spiti, although the lithology is somewhat different, the same three zones are probably present in the Otoceras Beds. Here we find a lower horizon of ferruginous limestone containing *Otoceras woodwardi*, *O.* cf. *undatum O. clivei*, together with *Episageceras dalailamae*, *Prosphingites nala*, *Lytophiceras sakuntala*, and several species of *Ophiceras*, and probably corresponding to Zone 1 *plus* a portion of Zone 2 of the Painkhanda area. This ferruginous limestone is followed by unfossiliferous sandy limestones weathering brown, corresponding possibly to the unfossiliferous portion of the Painkhanda Zone 2. Finally, grey limestones with *Ophiceras tibeticum*, *O.* cf. *demissum*, *O. chamunda*, *Lytophiceras sakuntala* and *Pseudomonotis griesbachi* (common), appear to be the equivalents of Zone 3. According to Diener, *Otoceras* in Spiti is confined to the lowest horizon, where it is rare ; in Painkhanda, *Otoceras* is found, though rarely, in Zone 3, where it is represented by a variety of *O. woodwardi*. Dr. Spath notes that in the East Greenland also *Otoceras* has been found to overlap *Ophiceras* and *Lytophiceras sakuntala* the most numerous fossil in the lowest Painkhanda zone, occurs in the highest as well as the lowest of the three Spiti horizons.

The combined fauna of the Otoceras Beds of the Himalaya, as listed by Diener and Bittner, comprises the following well preserved forms.[1]

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[1] *Mem.* XXXVI, Pt. 3. 17 (1912), *Pal. Ind.* Ser. XV, Vol. III, Pt. 2, 70-73 (1899) Dr. Spath's emendations as usual, in square brackets.

Brachiopoda—
Rhynchonella (*Norella*) *procreatrix* Bittn.

Lamellibranchiata—
Pseudomonotis (*Claraia*) *griesbachi* Bittn., } both found in the Lower Trias of southern
,, ,, *painkhandana* Bittn., } China.[1]
Avicula aff. *venetiana* Hauer,

Gastropoda—
Bellerophon cf. *vaceki* Bittn.

Cephalopoda—
Grypoceras brahmanicum (Griesb.),
Xenodiscus [*Glyptophiceras*] *himalayanus* (Griesb.),
Episageceras dalailamae Dien.,
Proptychites scheibleri Dien.,
Ophiceras medium Griesb.,
,, *tibeticum* Griesb.,
,, *platyspira* Dien.,
,, *serpentinum* Dien.,
,, *stricturatum* Frech and Noetl.,
,, [*Lytophiceras*] *sakuntala* Dien.,
,, [*Acanthophiceras*] *gibbosum* Griesb.,
,, [*Metophiceras*] *demissum* Oppel.,
,, [*Lytophiceras*] *ptychodes* Dien.,
,, ,, ,, *chamunda* Dien.,
Vishnuites pralambha Dien.,
Hungarites sp. [*Metotoceras dieneri* Spath],
Otoceras woodwardi Griesb.,
,, *undatum* Griesb.,
,, *clivei* Dien.,
,, *draupadi* Dien.,
,, *parbati* Dien.,
,, *fissisellum* Dien.,
"*Meekoceras*" [*Prionolobus*] *hodgsoni* Dien.,
Prosphingites [*Anotoceras*] *kama* Dien.,
,, ,, *nala* Dien.,

While *Ophiceras* is the predominating genus of the Cephalopoda in the topmost zone of the lower sub-stage, it is extremely rare and represented by a single species—*O. obtuso-angulatum* in the upper sub-stage, where it is replaced by forms which were originally included under the upper sub-stage genus *Meekoceras*. This corresponds to Spath's zone of "*Celtites*" *radiosus*, the lowest zone of the Gyronitan, and contains the following cephalopods :—

"*Meekoceras*" *rugosum* v. Krafft,
,, *jolinkense* v. Krafft (found also in the Lower Trias of Madagasaar),
,, *disciforme* v. Krafft,
,, cf. *discus* Waag.,
,, *tenuistriatum* v. Krafft (a passage form from *Kingites* to *Proptychites*)[2].
,, [*Prionolobus*] *lilangensis* v. Krafft,
,, ,, *lingtiense* v. Krafft,
,, [*Proptychities*] *markhami* v. Krafft,
,, [*Koninckites*] *haydeni* v. Krafft,
,, ,, *alterammonoides* v. Krafft,
,, ["*Aspidites*" ? *Koninckites*] *spitiense* v. Krafft,
,, [*Clypeoceras*] *ensanum* v. Krafft,
,, ["*Aspidites*"] *crassum* v. Krafft (a form intermediate between *Clypeoceras* and *Koninckites*),
"*Meekoceras varaha*" [*Koninckites kraffti* Spath],
"*Xenodiscus*" *radians* Waag.,
,, *lilangensis* v. Krafft,
"*Hedenstroemia*" *lilangensis* v. Krafft (a primitive species),
Grypoceras lilangense v. Krafft,

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[1] *Bull. Geol. Soc. China*. XVI, 303 (1937).

[2] L. F. Spath. *Cat. Ceph. Brit. Mus.*, Pt. IV, 158, (1934).

Before considering the upper stage of the Lower Trias, it should be mentioned that the following additional cephalopods belong also to the lower stage of the Lower Trias, but their particular horizon is not known :—

"*Meekoceras*" [? *Koninchites*] *boreale* Dien.,
,, [*Koninckites*] *kyokticum* v. Krafft,
,, *dubium* v. Krafft,
,, cf. *radiosum* Waag. (? *Kymatites typus* Waag.),
"*Aspidites*" [*Kingites*] *vidarbha* Dien.,
Proptychites typicus v. Krafft,
Xenodiscus [*Xenodiscoides*] *rigidus* Dien.,
,, ,, *rotula* Waag.,
,, ,, cf. *plicosus* Waag.,
Nannites [*Juvenites*] *hindostanus* Dien.,
,, ,, *herberti* Dien.,
Flemingites [*Euflemingites*] *guyerdeti* Dien.

The upper stage of the Lower Trias may be subdivided into three sub-stages : (i) the Hedenstroemia Beds, including in Spiti some 24 feet of unfossiliferous beds, (ii) a few feet of shales with bivalves, and (iii) the unfossiliferous Niti Limestone. The Hedenstroemia Beds[1] contain a fauna of uniform character, in which species of "*Xenodiscus*" (*Anakashmirites*) especially "*X* " [*Anakshmirites*] *nivalis*, *Hedenstroemia* and *Flemingites* predominate ; it probably corresponds to the middle and upper Gyronitan zones (those of *Prionolobus rotundatus* and "*Cellites*" *fallax*) plus the two zones of the Flemingitan, *Koninckites volutus* and *Flemingites flemingianus*. The best development of this sub-stage is seen at Muth in Spiti. It shows a considerable change from the fauna of the "Meekoceras" beds below it. Fossils, though numerous, are badly preserved, but the following cephalopods have been identified by Diener :—

Pleuronautilus dieneri v. Krafft,
"*Meekoceras*" *pseudoplanulatum* v. Krafft,
,, aff. *pilatum* Hyatt and Smith,
,, cf. *joharense* v. Krafft,
,, *solitarium* v. Krafft, (another passage form from *Kingites* to *Proptychites*),
Aspidites [*Pseudaspidites*] *muthianus* v. Krafft,
,, *superbiformis* Dien.,
,, [*Clypeoceras*] aff. *superbus* Waag.,
Koninckites [*Pseudaspidites*] *yudishthira* Dien.,
,, [? *Paranorites*] *giganteus* v. Krafft,
Xenodiscus [*Anakashmirites*] *kapila* Dien.,
,, [? *Anakashmirites*] *purusha* Dien.,
,, [*Anakashmirites*] *nivalis* Dien.,
,, cf. *trapezoidalis* Waag.,
S. ,, *asiaticus* v. Krafft (perhaps identical with *X.* (*Anakashmirites*) *nivalis*),
S. *Flemingites rohilla* Dien.,
S. ,, *muthensis* v. Krafft,
,, *griesbachi* v. Krafft,
,, *salya* Dien.,
S. "*Ceratites*" *pumilio* v. Krafft,
Prionites sp.,
Tirolites injucundus v. Krafft,
Nanites [*Juvenites*] *hindostanus* Dien.,
,, [*Juvenites*] *medium* Dien.,
Pseudosageceras multilobatum Noetl.,
S. *Hedenstroemia mojsisovicsi* Dien. [*Anahedenstroemia himalayica* Spath. *partim*],
,, (*Anahedenstroemia*) *muthiana* v. Krafft.,
Sibirites [? *Anasibirites*] *spitiensis* v. Krafft.
Proavites ("*Lecanites*") *sisupala* Dien.
S=having affinites with forms in the Ceratite Sandstone of the Salt Range.

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[1] Originally known as the "*Ceratites subrobustus* beds" ; it is most probable, however that the specimen of *Ceratites* (*Keyserlingites*) *subrobustus*, supposed to have been derived from this horizon fell from the overlying Muschelkalk or Anisian cliffs. (*Pal. Ind.*, Ser. XV, Vol. V., *Mem.* 2, 132 (1907)).

The Hedenstroemia Beds of Spiti and Garhwal are succeeded by a few feet of lithologically similar beds of shale and limestone, in which two fossiliferous horizons have been recorded by Hayden, a lower with large numbers of bivalves, the principal of which are *Pseudomonotis himaica* Bittn. and *P. decidens* Bittn., and an upper some 3 feet thick, with the three brachiopods *Rhynchonella griesbachi* Bittn.[1], *Norella kingi* Bittn. and *Retzia himaic* Bittn. From the latter horizon the cephalopod *Sibirites prahlada* is also recorded but it is very doubtful whether the single specimen labelled from this horizon did not come from a Lower Anisian (Beyrichitan) stage higher up.

The highest bed of the Lower Trias in Painkhanda and Spiti is the Niti Limestone, a massive, nodular, practically unfossiliferous limestone, some 50 feet in thickness. This gives rise to the most conspicuous scenic feature of the region rising in a steep escarpment above the slopes of older Triassic beds.

Lower Trias of Byans.—In Byans, the Lower Trias differs considerably from that of Spiti and Garhwal, and is represented by about 150 feet of chocolate-coloured limestone, and by the lowest portion of an overlying light grey limestone containing *Rhynchonella griesbachi* ; the chocolate-coloured limestone passes down through unfossiliferous passage beds into the Productus Shales. Numerous fossils have been obtained from a sandy rock in the vicinity of Jolinka and Kuti, near the base of the compact, chocolate limestone, indicating the lower stage of the Lower Trias : with the exception of *Ophiceras* cf. *serpentinum* which is characteristic of the Otoceras Beds, the species are members of the "*Meekoceras*" fauna and include : "*Meekoceras*" *boreale* Dien., "*M*" *dubium* v. Krafft, "*M.*" *jolinkense* v. Krafft, "*Aspidites*" ? [*Koninckites*] *spitiensis* v. Krafft, "A" [*Kingites*] *vidarbha* Dien.. *Proptychites typicus* v. Krafft, "*Xenodiscus*" *radians* Waag., and "*X.*" (*Xenodiscoides*) *rotula* Waag. The presence of the upper stage of the Lower Trias in higher layers of the Chocolate Limestone at Kalapani, Lilinthi, Jolinka and Kuti, is demonstrated by the occurrence of *Flemingites* cf. *griesbachi* v. Krafft, "*Hedenstrœmia mojsisovicsi*" Dien. and "*H.*" [*Parahedenstrœmia*] *acuta* v. Krafft. A faunule from near the top of the Chocolate Limestone at Jolinka is interesting in that it consists exclusively of species of "*Sibirites*" [*Anasibirites*]—a genus restricted in the Salt Range to the Upper Ceratite Limestone ; the species indentified include : "*Sibirites*" *spiniger* v. Krafft, "*S.*" *robustus* v. Krafft, and "*S.*" *stephanitiformis* v. Krafft. The specimen of "*Sibirites*" *spitiensis* from the Muth section in the Spiti valley is probably derived from a representative of this horizon in the Hedenstroemia Beds.

Correlation of the Lower Trias.—The Lower Trias of the Himalaya and that of the Salt Range possess a considerable number of species in common and the following table shows the inter-relationship. The most obscure point in this respect is the equivalent in the Salt Range of the Otoceras Beds, the most characteristic elements of whose fauna are absent in that area[2] ; it appears likely that they take the place of the unfossiliferous clay and shales in the Salt Range succession below the Lower Ceratite Limestone.

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[1] "*Ryhnchonella semiplecta*" of the 2nd Edition of this manual.

[2] *Pal. Ind.* Ser. XV, Vol. II, pt. 1, 177 (1897).

	Himalaya.	Salt Range.	
Lower Trias.	Zone of "*Sibirites*" *spiniger* (Byans)	Upper Ceratite Limestone	Lower Trias.
	Hedenstrœmia Beds	Ceratite Sandstone	
		Ceratite Marl	
	"*Meekoceras*" Beds	Lower Ceratite Limestone	
	Otoceras Beds	Unfossiliferous clay and shale	
	Productus Shales	(Upper Productus Limestone.)	

The *Otoceras-Ophiceras* fauna appears to be one of limited distribution, and is best developed in East Greenland where it occurs in beds 500 feet thick. In the Himalaya it occupies not more than two or three feet, and at Ussuri in Japan, the only other region where it has so far been recorded, the beds are greatly attenuated.[1] The "*Meekoceras*" and *Ophiceras* zones are widespread over the middle and lower Yang-tze valley in southen China, and include *Ophiceras* cf. *demissum* *O.* aff. *chamunda*, "*Meekoceras*" cf. *jolinkense*, "*Xenodiscus*" cf. *rigidus*, and "*Xenodiscus*" aff. *lilangensis*.[2] The corresponding fauna at Darwaz in Bokhara, with a doubtful "*Meekoceras*", is mainly a lamellibranch assemblage and indicates an approach to the northern shore of the sea in the more open portion of which the Himalayan deposits accumulated. "*Meekoceras*" and *Pseudoflemingites* (the so-called "*Ophiceras*") are present in Timor, and the former genus occurs in Armenia. With the Campil or Upper Werfen beds of the Alps the Lower Trias of the Himalaya shows a general parallelism, though the relationship of the two faunas is not very close. The true *Meekoceras* fauna of California, Idaho and other parts of the Pacific province belongs to a later stage of the Lower Trias (Owenitan), and is present in the Ussuri and Olenek areas of Siberia.

Middle Trias.—The Middle Trias is represented in the Himalaya by the Anisian and Ladinian stages. In Spiti, where it is best developed, the Ladinian exceeds the Anisian considerably in thickness. For reference, Dr. Spath's classificatory scheme is as follows :—

Ladinian or Ceratitan	Upper	Zone of *Ceratites archelaus.*		
	Lower .	Zone of *Ceratites reitzi* Upper.		
Anisian or Virgolorian.	Upper or Paraceratitan.	Zone of *Paraceratites trinodosus.* Zone of *Paraceratites binodosus.*	Middle	Mushelkalk.
	Lower or Beyrichitan.		Lower	

Anisian of Spiti and Garhwal.—The Anisian is just as uniform throughout Spiti and Painkhanda as the Lower Trias, and nearly every bed in the one can be matched in the other area. Good sections of the Anisian can be seen in the two classical Painkhanda localities of the Bambanag cliff above the Girthi valley, and the Shalshal cliff opposite Rimkin Paiar, a little below the confluence of the Barahoti and Chorhoti rivers, as well as in the Lilang and Lingti exposures in Spiti. Of the two stages into which the Anisian can be divided, the lower or Beyrichitan consists of 6 feet of thin-bedded grey limestones, partly alternating with shales ; ammonites, which prevail in the lower horizons, are gradually replaced by brachiopods which predominate in the upper. The following are the cephalopoda of the Lower Anisian, twelve species of which are peculiar to Spiti :—

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[1] L. F. Spath. *Meddelelser om Gronland*, Bd. 98, Nr. 2, 114-115 (1935).

[2] V. K. Ting. *Pal. Sin*, B. XV, Fasc. 1, 1 (1933).

S.G. "*Keyserlingites*" [*Durgaites*] *dieneri* Mojs.,
S. ,, *pahari* Dien.,
S. ,, *pagoda* Dien.,
S. ,, [*Ceratities*] aff. *bungei* Mojs.,
S. *Ceratities* (*Hollandites*) *vyasa* Dien.,
S. ,, (*Danubites*) cf. *kansa* Dien.,
S.G. *Dalmatites ropini* Dien.,
S. *Japonites* cf. *ugra* Dien.,
S. "*Stacheites*" *webbianus* Dien.,
S. "*Sibirites*" *prahlada* Dien. (probably the inner whorls of a *Durgaites*, and probably identical with the Timor form, "*Tirolites*" *meridianus* Welt.),
S. *Gymnites depauperatus* Dien.,
S. ,, aff. *sankara* Dien.,
S.G. *Monophyllites* (*Ussurites*) *hara* Dien. (*Eophyllites refractus* Spath),
S.G. ,, ,, *kingi* Dien. (*Ussurites* (?) *decipiens* Spath),
S. ,, (*Mojsvarites*) *Confucii* Dien.,
S. ,, ,, (*Leiophyllites*) *pradyumna* Dien.,
G. *Orthoceras* cf. *multilabiatum* Hauer,
G. ,, cf. *campanile* Mojs.

Of the brachiopods, *Rhynchonella mutabilis* Stol. has been collected from Spiti, and *Spiriferina stracheyi* Salt., [*Athyris Spirigera stoliczkai*] Bittn. (perhaps the equivalent of *Athyris strohmeyeri* Salt.), and *Rhynchonella dieneri* Bittn. from both Spiti and Garhwal ; other species are recorded but their stratigraphical position is not certain.

The most characteristic element in this fauna is the group of *Durgaites dieneri*. The astonishing resemblance of the adult form of this cephalopod to the adult form of *Keyserlingites subrobustus* ("*Ceratites subrobustus*") of the Siberian Olenek beds is quoted by Dr. Diener as an interesting case of convergence, there is believed to be no real affinity between the two ; the larval and adolescent stages differ markedly for, while the inner nucleus of the Siberian species resembles the mature stages of *Dinarites* (*Olekenites*) *spiniplicatus*, its Indian representative passes through stages resembling *Tirolites* and afterwards *Sibirites*.[1] Some of the cephalopods are akin to Alpine forms, *Monophyllites hara* [*Eophyllites refractus*] and the two *Orthoceras* species being more or less identical, but the brachiopods are all isolated types and differ considerably from Alpine species.

The Upper Anisian is composed of thick beds of hard, grey, concretionary limestone which has yielded a few brachiopods, lamellibranchs and gastropods, and a copious cephalopod fauna ; the latter is very uniform in Spiti and Painkhanda and constitutes one of the richest and most widely spread fossil horizons in the Himalaya. The following list has been compiled by Dr. Diener :—

Brachiopoda—

S. *Cœnothyris vulgaris* Schloth.,
S. *Mentzelia mentzeli* Dunk.,
S. ,, *koeveskalliensis* Suess.,

Lamellibranchiata—

S. *Posidonomya* aff. *pannonica* Mojs.,
S. *Lima* aff. *lineata* Desh.,
S. *Cadomorpha* (?) *hoydeni* Dien.,

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[1] C. Diener. *Mem.* XXXVI, 264-265 (1912).
S.=Spiti forms.
G.=Garhwal forms.

Gastropoda—
S. *Pseudomelania* sp.,
S. *Omphaloptycha* sp.,
S. *Tectospira gracilis* Blaschke.,
S. *Worthenia dieneri* Blaschke.
Cephalopoda—
S. *Orthoceras spitiense* Dien.,
S. *Mojsvaroceras kagae* Dien.,
S.A. *Germanonautilus* cf. *salinarius* Mojs.,
S. *Syringonautilus spitiensis* Stol.,
S. *Grypoceras griesbachi* Dien.,
S. „ aff. *palladii* Mojs. (Eastern Johar),
S. *Paranautilus bullocki* Dien.,
S.A. *Ceratites* [*Paraceratites*] *trinodosus* Mojs.,
S.G. „ [*Paraceratites*] *thuilleri* Opp.,
S. „ *himalayanus* Blanf.,
S. „ aff. *abichi* Mojs.,
S. „ *superbiformis* Dien.,
S. „ *truncus* Opp.,
S. „ *devasena* Dien.,
S. „ *padma* Dien.,
S.G. „ *kamadeva* Dien.,
G. „ *royleanus* Dien.,
G. „ (*Gymnotoceras*) aff. *geminatus* Mojs.,
G. „ (*Hollandites*) *arjuna* Dien.,
G. „ „ *nalikanta* Dien.,
G. „ „ *srikanta* Dien.,
G. „ „ *narada* Dien.,
S. „ „ *hidimba* Dien.,
S.G. „ „ *voidi* Opp.,
S.G. „ „ *ravana* Dien.,
S.G. „ „ *airavata* Dien.,
S.G. „ „ *visvakarma* Dien.,
S.G. „ „ *dungara* Dien.,
S.G. „ „ *moorei* Dien.,
S.G. „ „ *vyasa* Dien.,
S.G. „ „ *cecilii* Dien.,
S. „ (*Salterites*) *oberhummeri* Dien.,
S. „ (*Haydenites*) *hatscheki* Dien.,
G. *Ananorites monticola* Dien.,
G. *Japonites sugriva* Dien.,
G. „ *chandra* Dien.,
S.A. „ cf. *dieneri* Mart.,
G. *Beyrichites gangadhara* Dien.,
G. „ [? *Arctoceras*] *affinis* Mojs.,
G. „ *rudra* Dien.,
S. „ *proximus* Opp.,
S.G. „ *khanikoffi* Opp.
S.G. „ *kesava* Dien.,
S. *Cuccoceras yoga* Dien.,
S. *Isculites hauerinus* Stol.,
S.A. *Acrochordiceras* cf. *carolinae* Mojs.,
S. „ aff. *pustericum* Mojs.,
S.G. „ *balarama* Dien.,
S.G.A. *Sturia sansovinii* Mojs.,
S.G. *Budahaites rama* Dien.,
S.G. *Gymnites jollyanus* Opp.,
S.G. „ *sankara* Dien.,
S.A. „ *incultus* Beyr.,
S.A. „ cf. *humboldti* Mojs.,
S. „ *mandiva* Dien.,
S. „ *kirata* Dien.,
S. „ *religiosus* Dien.,

S.=Spiti form.
G.=Garhwal form.
A.=Definitely or most probably identical with an Alpine form

Cephalopoda—*contd.*

S. *Gymnites* aff. *subclausus* Hauer,
S. *Anagymnites lamarcki* Opp.,
S. ,, cf. *acutus* Hauer,
S. ,, *torrensi* Dien.,
S. *Monophyllites sphaerophyllus* Hauer,
S. *Pinacoceras rajah* Dien.,
S. *Ptychites cognatus* Opp.,
S. ,, *sukra* Dien.,
S. ,, *asura* Dien.,
S. ,, *durandi* Dien.,
S. ,, *vidura* Dien.,
S. ,, *malletianus* Stol.,
S. ,, *impletus* Opp.,
S. ,, *mangala* Dien.,
S.G. ,, *rugifer* Opp.,
S.G. ,, *cochleatus* Opp.,
S.G.A. ,, *everesti* Opp.,
S.G. ,, *gerardi* Blanf.,
S.G. ,, *sumitra* Dien.,
S.G. ,, *mahendra* Dien.,
S.A. *Joannites* cf. *proavus* Dien.,
S.A. *Proarcestes balfouri* Opp., (*P. escheri* of Mojsisoivcs),
S. ,, aff. *bramantei* Mojs.,

On the southern slope of the Uttardhura, between Milam in Johar and the Girthi valley in Painkhanda, a faunule of a rather peculiar character has been collected, including the three following species which are not found in other parts of Spiti and Painkhanda : *Orthoceras* cf. *campanile* Mojs., *Acrochordiceras joharense* Dien. and *Pseudodanubites dritarashtra* Dien.

On the eastern slope of the Hop Gadh, a stream in Hundes five marches beyond the village of Nelang in Tehri Garhwal, Mr. Griesbach collected the following Upper Anisian forms, but the horizon has not been thoroughly explored and would probably yield a larger number of well-preserved fossils : *Ceratites* (*Hollandites*) *hidimba* Dien., *Beyrichites khanikoffi* Opp., *Ptychites govinda* Dien. and *Proarcestes balfouri* Opp.

Anisian of Byans.—Like the Lower Trias, the Anisian begins to change its facies in the northeast corner of Kumaon (Byans) as it approaches the boundary of Nepal, where it is developed in the form of pure, light grey limestone with no trace of shale partings. The Lower Trias zone of *Rhynchonella griesbachi* is included in this limestone which supersedes the Chocolate Limestone. About 50 feet above the top of the latter, within the uniform mass of the light grey limestone, is a layer of brachiopods representing the zone of *Spiriferina stracheyi* and containing in addition to that species *Athyris stoliczkai* Salt and *Dielasma himalayanum* Bittn. ; the cephalopods, *Keyserlingites* and *Durgaites* are not, however, recorded. The characteristic Alpine Muschelkalk species, *Rhynchonella trinodosa* Bittn. has been found in the Byans Anisian but whether in this horizon or from the Upper division is uncertain. Above the brachiopod layer is a bed full of Upper Anisian cephalopods, including the following species, the specimens of which usually show severe distortion :—

Atractites smithi Dien.,
Orthoceras cf. *campanile* Mojs. (Alpine form),
Grypoceras griesbachi Dien.,

S.=Spiti form.
G.=Garhwal form.
A.=Definitely or most probably identical with an Alpine form.

Mojsvaroceras aff. *morlotum* Mojs.,
,, *nivicola* Dien.,
Ceratites [*Paraceratites*] *thuilleri* Opp.,
,, *kuvera* Dien.,
,, [*Philippites*] *jolinkanus* Dien.,
,, (*Hollandites*) *vyasa* Dien.,
,, ,, *roxburghi* Dien.,
,, (*Peripleurocyclus*) *smithianus* Dien.,
Smithoceras drummondi Dien.,
Sageceras sp.,
Buddhaites rama Dien.,
Bukowskiites colvini Dien.,
Pinacoceras loomisii Dien.,
Gymnites jollyanus Dien.,
,, *kirata* Dien.,
,, *sankara* Dien.,
Ptychites sahadeva Dien.,

From the above list of types, half of which have not yet been found in any Himalayan district outside Byans, it is evident that the lithological change is accompanied by a faunistic one as we approach Nepal.

Correlation of the Himalayan Anisian.—Although remarkably similar in stratigraphical development to the Lower and Middle Muschelkalk of the Eastern Alps, the Himalayan equivalent has a number of peculiar faunistic elements of its own, including especially the presence in its upper portions of sub-genera of *Ceratites* such as *Hollandites* (a predominant type), *Peripleurocyclus*, *Salterites*, *Haydenites*, *Pseudodanubites*, *Bukowskiites* and *Keyserlingites*; *Smithoceras durandi* is a particularly abberrant form and the primitive ancestor of the Upper Triassic Juvavitinae. Two species of the Indian sub-genus *Hollandites*, and one of *Gymnotoceras* occur in the Nevada fauna of North America and the last is also found in the Olenek area of Siberia though not in the Alps.

Ladinian of Spiti.—The Ladinian stage, included with the Middle Trias is represented by a fossiliferous succession in Spiti up into which the Anisian passes so gradually, both lithologically and faunistically, that it is impossible to fix any definite boundary line between them. At Kaga, a village on the left side of the Parahio valley, and at Muth in the Thanam valley, there is a passage bed, closely associated with the topmost Anisian horizon and yielding a fauna which is of a decidedly Ladinian aspect and may perhaps correspond to the Buchenstein of the Tyrol; ten of the species (d) range up into the Daonella Shales above, and two (m) down into the Upper Anisian :—

Brachiopoda—
d. *Athyris* (*Spirigera*) *hunicus* Bittn.

Cephalopoda—
Arpadites cf. *lissarensis* Mojs.,
d. ,, *rimkinensis* Mojs.,
d. *Hungarites pradoi* d'Arch.,
,, aff. *mojsisovicsus* Boeckh.,
d. *Protrachyceras longobardicum* Mojs.,
d. ,, *spitiense* Dien.,
d. ,, *cautleyi* Dien.,
d. *Thanamites bicuspidatus* Dien.,
,, *bannaensis* Dien.,
d. *Rimkinites nitiensis* Mojs.,
d. ,, *edmondi* Dien.,
Sturia sp.,

Cephaloppoa—*contd.*

m. d. *Ptychites gerardi* Blanf.,
Megaphyllites jarbas Muenst.,
d. *Joannites kossmati* Dien.,
m. ,, cf. *proavus* Dien.,
Proarcestes cf. *balfouri* Opp.

The Daonella Shales consist of 160 feet of black, thin-bedded, shaly limestone and earthy shale with some bands of hard, black limestone weathering brown; from an horizon near their base they have yielded the following typical Ladinian fauna :—

Brachiopoda—

Athyris (*Spirigera*) *hunicus*, Bittn.,
Rhynchonella cf. *theobaldiana* Stol.

Lamellibranchiata—

t. *Daonella lommeli* Wissm.,
,, *indica* Bittn.,

Cephalopoda—

Ceratites narsingha Dien.,
Arpadites rimkinensis Mojs.
t. *Hungarites pradoi* d' Arch.,
Thanamites bicuspidatus Dien.,
Rimkinites nitiensis Mojs.,
,, *edmondi* Mojs.,
t. *Anolcites laczkoi* Dien.,
t. *Protrachyceras archelaus* Lbe.,
,, *spitiense* Dien.,
t. ,, *ladinum* Mojs.,
t. ,, cf. *longobardicum* Mojs.,
t. ,, cf. *regotedanum* Mojs.,
Sturia sp.,
Gymnites calosoma Dien.,
Pinacoceras aff. *damesi* Mojs.,
Ptychites gerardi Blanf.,
Joannites cf. *proavus* Dien.,
,, cf. *tridentinus* Mojs.,
,, *kossmati* Dien.,
Proarcestes bicinctus Mojs.,
,, cf. *balfouri* Opp.,
,, aff. *esinensi* Mojs.,
t=Tyrolese Wengen forms.

The Daonella Shales are succeeded in Spiti by the (Daonella) Limestone, a dark homogeneous, splintery rock about 145 feet thick containing *Daonella lommeli* throughout the lower 100 feet or so. In it are represented both the highest Ladinian and the lowest Carnic fauna, the beds forming a passage between the Middle and Upper Trias; Diener suggests that the lowest 80 feet of this sub-division should be included with the Ladinian, making the total of the latter stage about 240 feet. The fauna of the Daonella Limestone is as follows :—

Crinoidea—

Traumatocrinus sp.

Brachiopoda—

Rhynchonella cf. *rimkinensis* Bittn.,

Lamellibranchiata—

Daonella lommeli Wissm.,
,, *indica* Bittn.,
,, aff. *cassianae*.

Cephalopoda—
Phloioceras deliciosum Dien.,
Styrites lilangensis Dien.,
Celtites trigonalis Dien.,
,, *perauritus* Dien.,
Rimkinites nitiensis Mojs.,
Monophyllites cf. *wengensis* Klipst.,
Joannites cf. *klipsteini* Mojs.,
,, *kossmati* Dien.,

Ladinian of Kumaon.—The Daonella beds dwindle eastwards towards Painkhanda, in which locality *Daonella lommeli* is not known and the sub-stage appears to be represented by a limestone of small thickness and lithologically like that of the Anisian ; it is very poor in characteristic Ladinian fossils but there is no hiatus between the Upper Anisian and the Carnic stages. Opposite the Ralphu glacier in the Lissar valley of Johar, a dark grey limestone has yielded a small fauna which has a somewhat older aspect than that of the Traumatocrinus Limestone, but there is no definite proof of its Ladinian age. In Byans there is no palaeontological evidence whatever of the Ladinian stage.

Relationship of the Himalayan Ladinian.—During the Ladinian epoch we still find a close relationship between the Himalayan and Mediterranean faunas; out of 30 species the Indian fauna possesses four only which show faunistic elements peculiar to itself. Similar affinites are seen in the passage beds below.

Upper Trias of Spiti and Garhwal.—In the Upper Trias there are two distinct rock groups, a lower in which marly, clayey and arenaceous sediments predominate over calcareous, and an upper consisting of pure limestones and dolomites. This lithological division does not correspond to fannistic changes. The separation, for instance, of the Carnic from the Noric is not marked lithologically; in fact, the uniform mass of grey limestones and dolomites which follow the more shaly succession includes the equivalents not only of the Noric and Rhaetic Dachsteinkalk of the Tyrolese Alps but even of the Lias and Oolite.[1] The more argillaceous beds of the lower group form slopes from which tower cliffs and jagged peaks of the younger dolomite and limestone.

Carnic of Spiti.—In the Lilang section of Spiti, the Carnic stage is at least 1,600 feet thick and includes, as we have seen, the upper portion of the Daonella Limestone. The lower limit of this stage may be drawn at a bed containing *Joannites thanamensis* Dien. ; that portion of the limestone above this layer has yielded *Halobia* cf. *comata* Bittn., a species typical of the Julian sub-stage in the Himalaya.

There are four fossil horizons in the Carnic stage of Spiti above the Halobia Limestone.[2] The lowest of these, lying almost immediately above the limestone, is a band of black concretions containing numerous ammonoids among which are :—

Trachyceras aff. *arias* Mojs.,
,, sp. (group of *acanthica*),
**Carnites floridus* Wulf,
* ,, cf. . .*nodiger* Dien.,
**Joannites cymbiformis* Wulf,
Monophyllites aff. *simonyi* Hauer.

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[1] C. Diener. Mem. XXXVI 287 (1912).

[2] *Halobia* and *Daonella* are regarded by some as synonymous genera. The term *Halobia* is generally used for forms in which an anterior wing is represented by a smooth non-projecting area, the term *Daonella* for forms in which neither an anterior nor a posterior wing is present. Whether or not the two forms are best regarded as sub-genera of a single genus, it is convenient to make use of them and to retain the names proposed by Stoliczka for those sub-stages of the Ladinian and Carnic named after them.

*Genera peculiar to India.

The three species asterisked are found in the zone of *Trachyceras aonoides* of the Julian sub-stage of the Alps, and of this zone and the overlying zone of *Carnites flonidus* the above fossil horizon appears to be the homotaxial equivalent.

This horizon of black concretions is followed by grey earthy shales with intercalations of grey shaly limestone, one of them 20 feet thick. Forty feet above the latter and about 300 feet above the Holobia Limestone occurs the second fossil horizon, identified in the Lilang section and also to the northwest of Muth. It has yielded a badly-preserved ammonite referred with some doubt to *Paratropites*, but from both localities a rich brachiopod and bivalve fauna has been collected, including :—

Brachiopoda—

Rhynchonella laucana Bittn.,
,, ,, var. *lilangensis* Bittn.,
,, cf. *semiplecta* Muenst.,
,, *freshfieldi* Dien.,
,, *himaica* Dien.,
,, of. *bajuvarica* Bittn.,
Austriella aff. *nux* Suess,
Spiriferina gregaria Suess,
,, aff. *shalshalensis* Bittn.,
,, *orophita* Dien.,
,, *deodarae* Dien.,
Mentzelia mentzeli Diean.,
**Aspilothyris kruffti* Dien.,
Dielasma julicum Bittn.,
,, *haydeni* Dien.,
Cruratula (?) *indica* Dien.

Lamellibranchiata—

**Lilangina nobilis* Dien. (genus allied to *Cassianella* Beyr. and *Hoernesia* Lbc.),
**Pomarangina haydeni* Dien. (genus having resemblances to *Physocardia* Woehrmann *and Pachycardia* v. Hauer).
Lima aff. *alternans* Bittn.

Above this continues the series of shaly limestones, earthy shales, calcareous shales and hard, dark, limestone intercalations. Six hundred feet above the brachiopod bed, or 900 feet above the Halobia Limestone, is a bed of nodular limestone, 15 feet thick, forming a part of the Tropites beds. At Lilang and Tikba this horizon is rich in badly preserved cephalopoda including :—

Clydonautilus acutilobatus Dien.,
Germanonautilus cf. *breunneri* Hauer.
Styrionautilus cf. *sauperi* Hauer,
Pleuronautilus aff. *wulfeni* Mojs.,
Tropites cf. *subbullatus* Hauer.,
,, *discobullatus* Mojs.,
,, cf. *torquillus* Mojs.,
,, aff. *paracelsi* Mojs.,
Paratropites tilkhensis Dien.,
Trachysagenites cf. *herbichi* Mojs.,
,, *galeatus* Dien.,
Discotropites aff. *plinii* Mojs.,
Anatomites cf. *bacchus* Mojs.,
Jovites spectabilis Dien (said to have been found also 70 feet higher up),
,, cf. *siculus* Gemm.,
Sandlingites aff. *reyeri* Mojs.,
,, aff. *castellii* Mojs.,
Clionites heraclitiformis Dien.,
Proarcestes cf. *gaytani Klipst.*

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*Genera peculiar to India.

Noric elements are completely absent from this fauna which is the homotaxial equivalent of the Alpine *Tropites subbullatus* zone (Tuvalic sub-stage). European affinites predominate and peculiar types are in the minority.

After a further 200 feet of shaly limestone and calcareous shales come 300 feet of dolomitic limestone which has yielded a few badly preserved fossils with Carnic affinites, belonging also apparently to the Tuvalic sub-stage.

Brachiopoda—

Dielasma julicum Bittn.,
Terebratula aff. *piriformis* Suess,
Spriferina aff. *shalshalensis* Bittn.

Lamellibranchiata—

Lima cf. *austriaca* Bittn.,
Halobia aff. *superba* Mojs.,
Daonella aff. *styriaca* Mojs.

Carnic of Garhwal.—The thinning-out eastward noted in the Middle Trias is more marked in the case of the Carnic stage which in Painkhanda is only some 825 feet thick, little more than half of what it is in the Spiti area. In Painkhanda the development of the Carnic stage is more uniform and there are fewer distinguishable stratigraphical horizons. Corresponding to most of the 150 feet of Halobia Limestone in Spiti is the Traumatocrinus Limestone, barely 10 feet thick, separated from the *Ptychites* zone of the Upper Anisian by an insignificant thickness of beds which, as already mentioned, may represent the Ladinian and are exposed in the Shalshal and Bambanag cliffs. The Julian age of the limestone is indicated by its rich faunæ in which European affinities are strongly marked :

Crinoidea—

Traumatocrinus sp.

Brachiopoda—

Athyris (*Spirigera*) *hunica* Bittn.,
(*Retzia*) aff. *ladina* Bittn.,
Aulacothyris nilangensis Bittn.
Rhynchonella rimkinensis Bittn.,
Austriella aff. *middlemissi* Bittn.,
Norella kingi, var. *tibetica* Bittn.

Lamellibranchiata—

Daonella indica Bittn.,
,, aff. *obliqua* Mojs.,
Avicula aff. *seisiana* Broili,
Pecten aff. *subalternans* Bittn.,
Heminajas cf. *woehrmanni* Waag. (belonging either to the Trigoniidae (*Myophoria*) or, according to Zittel, to the Cardiniidae),

Cephalopoda—

Proclydonautilus cf. *budhaicus* Dien.,
Grypoceras rimkinense Dien.,
,, *stirlingi* Dien.,
**Joannites cymbiformis* Wulf.
,, *klipsteini* Mojs,
,, *kossmati* Dien.,
,, *mojsvari* Dien.,
**Proarcestes* cf. *ausseanus* Hauer,
**Lobites* (*Coroceras*) cf. *delphinocephalus* Hauer,
,, ,, *valdecucullatus* Dien.,
**Monophyllites* cf. *simonyi* Hauer,
,, (*Mojsvarites*) *agenor Muenst.*,

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*Identical with or closely allied to European forms.

Cephalopoda—*contd.*

- *Juvavites* (*Anatomites*) sp.,
- **Isculites* cf. *heimi* Mojs.,
- *Celtites contractifrons* Dien.,
- **Carnites* cf. *floridus* Wulf.,
- **Placites* cf. *polydactylus*, var. *oldhami* Mojs.,
- *Rimkinites nitiensis* Mojs.,
  - ,, *edmondi* Mojs.,
- *Arpadites rimkinensis* Mojs.,
  - ,, (*Dittmarites*) cf. *circumscissus* Mojs.,
  - ,, ,, aff. *ladion* Dittm.,
- *Clionites* aff. *dorae* Mojs.,
- **Trachyceras austriacum* Mojs.,
  - ,, ,, var. *tibetica* Mojs.,
- *Protrachyceras* aff. *arion* Mojs.,
  - ,, sp. (group of *furcosa*),
- *Sirenites cookei* Dien.,
- *Girthiceras pernodosum* Dien.

Above the Traumatocrinus Limestone is a thin limestone which is interesting in that it is the highest horizon to which *Daonella indica* reaches ; in it have been found : *Athyris* (*Norella*) *kingi*, *N. tibeteica*, *Spirigera honica*, *Aulothyris nilangensis* and *Daonella indica.*

Succeeding this limestone is a thick sequence of dark, calcareous shales and shaly limestones, between 650 and 800 feet thick, well exposed in the cliffs of Shalshal and Bambanag. Cephalopods and bivalves occur throughout, more especially in the lower beds. *Daonella* is replaced by species of *Halobia* of the *rugosa* group, *H. comata* being a very characteristic form. The following fossils, most of them collected from Lauka, between Uttardhura and the Girthi valley, have been determined, the brachiopods by Bittner and the cephalopods by Mojsisovics,[1] and to them must be added several specifically indeterminable forms belonging to the genera, *Juvavites*, *Sagenites*, *Styrites*, *Tibetites*, *Paracladiscites*, *Megaphyllites*, *Proarcestes* and *Clydonautilus.*

Brachiopoda—

- *Spiriferina shalshalensis* Bittn.,
- *Retzia schwageri*, var. *asiatica* Bittn.,
- *Rhynchonella laucana* Bitten.

Lamellibranchiata—

- *Halobia comata* Bittn.,
  - ,, *fascigera* Bittn.,
- *Avicula girthina* Bittn.,
- *Cassianella* sp.

Cephalopoda—

- *Pleuronautilus tibeticus* Mojs.,
- *Jovites* aff. *dacus* Mojs.,
- *Discotropites* aff. *plinii* Mojs.,
- *Juvavites* cf. *tonkinensis* Dien.,
- *Anatomites bambanagensis* Mojs.,
  - ,, *eugenii* Mojs.,
  - ,, *caroli* Mojs.,
- *Greisbachites hanni* Mojs.,
- *Hypocladiscites subaratus* Mojs.,
- *Placites* aff. *perauctus* Mojs.,
  - ,, *polydactylus* Mojs., var. *oldhami* Mojs.,
- *Mojsvarites eugyrus* Mojs.,
- *Dischopyllites ebneri* Mojs.

This thick sequence, together with the thin limestone below it, must also be included in the Julian sub-stage.

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[1] *Pal. Ind. Sor.* XV, Vol. III, Pts. 1 and2 (1899).

*Identical with or closely allied to European forms

Upper Trias of Byans.—In Byans, the Upper Trias is so crushed and disturbed and most of its fossil horizons are so little known that its sub-division has not been made in the same detail as it has in the case of Johar, Painkhanda and Spiti. From the Upper Trias of the latter localities the Byans sequence differs considerably. The Carnic stage appears to be represented by the upper part of the blue grey limestone, the lower portion of which has yielded Mushelkalk fossils, but from the top-most bed, the famous "Tropites Limestone", has been collected an unusual association of Carnic and Noric fossils. Of the 250 feet of this blue grey limestone Diener has estimated that 170 feet belong to the Carnic stage, a small figure when compared with the 825 feet in Painkhanda and the much greater thickness in Spiti. The following fauna from the Tropites Limestone has been described by Professor Diener and is the richest fauna so far found in the Himalaya[1] :—

Brachiopoda—
Rhynchonella angulifrons Bittn.

Lamellibranchiata—
Halobia cf. *fascigera* Bittn.,
,, cf. *comata* Bittn.,
Avicula aff. *caudata* Stopp.,
,, aff. *tofanae* Bittn.

Cephalopoda—
Atractites cf. *ellipticus* Mojs.,
,, cf. *convergens* Hauer,
Orthoceras cf. *triadicum* Mojs.,
,, cf. *dubium* Hauer,
Grypoceras aff. *mesodicum* Hauer,
Proclydonautilus griesbachiformis Dien.,
Pinacoceras parma Mojs.,
,, *metternichii* Hauer,
,, cf. *rex* Mojs.,
,, *beecheri* Dien.,
Placites polydactylus Mojs., var. *oldhami* Mojs.,
,, aff. *perauctus* Mojs.,
Bambanagites kraffti Dien.,
Carnites cf. *floridus* Wulf,
Monophyllites jarbas Muenst.,
Discophyllites ebneri Mojs.,
Arcestes dicerus Mojs.,
,, *bicornis* Hauer,
,, *subbicornis* Mojs.,
Proarcestes cf. *gaytani* Klipst.,
,, aff. *zitteli* Mojs.,
,, cf. *sturi* Mojs.,
,, aff. *sublabiatus* Mojs.,
Stenarcestes aff. *ploysphinctus* Mojs.,
,, aff. *subumbilicatus* Mojs.,
Cladiscites cf. *neortus* Mojs.,
,, aff. *morosus* Mojs.,
Lobites cf. *ellipticus* Hauer,
Helictites cf. *geniculatus* Hauer,
,, cf. *subgeniculatus* Mojs.,
,, aff. *beneckei* Mojs.,
,, *canningi* Dien.,
Phormedites fasciatus Dien.,
,, aff. *juvavicus* Mojs.,
Buchites cf. *hilaris* Mojs.,
,, *emersoni* Dien.,

Cephalopoda—*contd.*
Thisbites meleagri Mojs.,
,, *ronaldshayi* Dien.,
,, *campbelli* Dien.,
Parathisbites cf. *scaphitiformis* Hauer,
,, cf. *hyrtli* Mojs.,
,, *windhami* Dien.,
,, *nodiger* Dien.,
Jellinekites barnadi Dien.,
,, *saundersi* Dien.,
,, *hoveyi* Dien.,
Arpadites tassilo Mojs.,
Dittmarites rawlinsoni Dien.,
,, aff. *lilli* Gumb.,
,, *trailli* Dien.,
,, *trailliformis* Dien.,
,, *teragadhensis* Dien.,
Trachypleuraspidites griffithi Dien.,
,, *massoni* Dien.,
Steinmannites cf. *lubbocki* Mojs.,
Daphnites aff. *ungeri* Mojs.,
Dionites aff. *caesar* Mojs.,
Drepanites schucherti Dien.,
,, *eastmani* Dien.,
,, aff. *marsyas* Mojs.,
Cyrtopleurites freshfieldi Dien.,
,, aff. *aggrippinae* Mojs.,
Tibetites cf. *ryalli* Mojs.,
Anatibetites kelvini Mojs.,
,, *hobsoni* Dien.,
Paratibetites adolphi Mojs.,
,, cf. *bertrandi* Mojs.,
,, cf. *geikiei* Mojs.,
,, aff. *tõrnquisti* Mojs.,
,, *wheeleri* Dien.,
Acanthinites hogarti Dien.,
Himavatites watsoni Dien.,
Polycyclus henseli Opp.,
Clionites gracilis Dien.,
,, aff. *hughesi* Mojs.,
,, aff. *aberrans* Mojs.,
,, aff. *dolloanus* Mojs.,
,, *stauntoni* Dien.,
Protrachyceras ansoni Dien.,
Sandlingites cf. *oribasus* v. Dittm.,
,, *pearsoni* Dien.,
,, *tuckeri* Dien.,
,, aff. *archibaldi* Mojs.,

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[1] *Pal. Ind.* Ser. XV, Vol. V, Mem. 1 (1906).

Cephalopoda—*contd.*

Sirenites trachyceratoides Dien.,
,, aff. *kohanyi* Mojs.,
,, *pamphagus* v. Dittm.,
,, *agriodus* v. Dittm.,
,, cf. *argonautae* Mojs.,
,, *argonautaeformis* Dien.,
,, cf. *dianae* Mojs.,
,, *evae* Mojs.,
,, *alixis* Dien.,
,, *vredenburgi* Dien.,
Anasirenites cf. *menelaus* Mojs.,
,, *greeni* Dien.,
Distichites sollasi Dien.,
,, *falconeri* Dien.,
,, aff. *megacanthus* Mojs.,
,, aff. *celticus* Mojs.,
,, aff. *atropus* v. Dittm.,
,, aff. *minos* Mojs.,
,, cf. *harpalos* v. Dittm.,
,, *younghusbandi* Dien.,
,, *reynoldsi* Dien.,
,, *ectolcitiformis* Dien.,
Ectolsites hollandi Dien.,
,, *arietiformis* Dien.,
,, *duncani* Dien.,
,, aff. *hochstetteri* Mojs.,
Isculites smithii Dien.,
,, *hemi* Mojs.,
,, aff. *obolinus* v. Dittm.,
Halorites aff. *procyon* Mojs.,
Jovites daciformis Dien.,
,, *spectabilis* Dien.,
Gonionotites gemmellaroi Dien.,

Cephalopoda—*contd.*

Parajuvavites jacquini Mojs.,
Anatomites specious Dien.,
,, cf. *crasseplicatus* Mojs.,
,, cf. *fischeri* Mojs.,
,, cf. *theodori* Mojs.,
,, *edgari* Mojs.,
,, *beresfordi* Dien.,
Didymites tectus Mojs.,
,, *kitchini* Dien.,
,, aff. *quenstedti* Mojs.,
,, aff. *subglobus* Mojs.,
Metasibirites philippii Dien.,
Discotropites kraffti Dien.,
,, *mojsisovicsi* Dien.,
,, cf. *sandlingensis* Hauer,
Margarites cf. *auctus* v. Dittm.,
,, *georgi* Mojs.,
,, cf. *circumspinatus* Mojs.,
,, *sushena* Dien.,
,, *devasena* Dien.,
Tropites subbullatus Mojs.,
,, cf. *fusobullatus* Mojs.,
,, cf. *discobullatus* Mojs.,
,, *estellae* Mojs.,
,, aff. *acutangulus* Mojs.,
,, *wodani* Mojs.,
,, cf. *paracelsi* Mojs.,
,, *jalandhara* Dien.,
,, *manasa* Dien.,
,, *kalapanicus* Mojs.,
Anatropites nihalensis Dien.,
,, *margaritiformis* Dien.,
Paratropites lilinthicus Dien.,
Tropiceltites arietitoides Dien.,

From a bed occupying a stratigraphical position more or less equal to that of the Tropites Limestone, and cropping out near Kalapani in the Upper Kali area, Heim and Gansser have collected many fossils, among which Professor Jeannet has recognised the following additional forms[1] :—

Lamellibranchiata—
Halobia styriaca Mojs.
Cephalopoda—
Dimorphites sp.,
Anatomites cf. *brocchi* Mojs.,
Molengraaffites cf. *compressus* Walt.,
Styrites cf. *signatus* v. Dittm.,
Paratibetites angustisellatus Mojs.,
Hauerites cf. *rarestriatus* Hauer,
Metacarnites sp.,
Sirenites cf. *elegans* Mojs.,
Cladiscites cf. *pusillus* Mojs.,
Arcestes cf. *piae* Dien.,
Gymnites sp.,
Palcites sakuntala Mojs.,
Proclydonautilus cf. *acutilobatus* Dien.

Correlation of the Tropites Limestone.—Of the 155 species of cephalopods in the Tropites Limestone many are identical with members of the Upper Triassic fauna of the Mediterranean, and the bulk of the remainder are closely allied to the same. The relationship to the Mediterranean is thus very strongly marked. The Tropites Limestone has many important types in common with the zone of *Tropites subbullatus* in the Carnic stage of the Alps, but there is at the same time a Noric element of almost equal importance in the limestone, many of the ammonite species being identical with or closely allied to species from Hallstatt Limestone of the Alps or the Halorites Limestone of Painkhanda. The absence of transitional forms makes it difficult to regard the limestone as a Carnic-to-Noric passage bed, and Diener's suggestion that the close association of the two faunas may be due to a cessation of sedimentation, seems more acceptable. In this case, the thin Tropites Limestone, which is not more than three feet thick, would be represented in the Painkhanda area by the upper portion of the beds with *Halobia comata*, the nodular limestone following, and the Halorites beds above that, while in Spiti its equivalent would be the Tropites Shales, the Dolomitic limestone with *Lima* cf. *austrica*, and the Juvavites beds, a succession totalling some 1,400 feet.

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[1] *Denksch. d. Schwiz. Nat. Gesells.* Bd., LXXIII, 111 (1939).

Lower Noric of Spiti.—Following conformably upon the Dolomitic limestone, which forms the uppermost portion of the Carnic stage in Spiti, are the Juvavites beds or lower subdivision of the Noric stage. In the Lilang section they are exposed as brown-weathering limestones alternating with shales and sandstones, totalling about 500 feet; the topmost beds are concretionary limestones. Cephalopods, especially ammonites of the genus *Juvavites* are common in the upper portion of this sub-stage. The fauna of the Juvavites beds comprises the following :—

Brachiopoda—
    Dielasma aff. *julicum* Bittn.

Lamellibranchiata—
    Halobia aff. *fascigera* Bittn.,
    Pecten " *Variamusium* " *margariticostatus* Dien.,
    ,, aff. *moniliferus* Muenst.,
    Lima cf. *serraticosta* Bittn.,
    Homomya aff. *larianae* Stopp.,
    Mytilus aff. *rugosus* Roem.,
    Mysidioptera sp.

Cephalopoda—
    Atractites cf. *alveolaris* Quenst.,
    Paranautilus arcestiformis Dien.,
    Pleuronautilus aff. *kossmati* Dien.,
    ,, cf. *tibeticus* Mojs.,
    Indonautilus cf. *kraffti* Mojs.,
    Dittmarites lilliiformis Dien.,
    ,, cf. *trailliformis* Dien.,
    Clionites cf. *hughesi* Mojs.,
    Metacarnites footei Dien.,
    ,, *hendersoni* Dien.,
    Pinacoceras aff. *parma* Mojs.,
    Tibetites cf. *ryalli* Mojs.,
    Anatibetites kelviniformis Dien.,
    Paratibetites tornquisti Mojs.,
    ,, aff. *wheeleri* Dien.,
    Juvavites angulatus Dien.,
    ,, aff. *ehrlichi* Hauer.,
    Anatomites aff. *melchioris* Mojs.,
    ,, aff. *caroli* Mojs.,
    ,, aff. *alphonsi* Mojs.,

Lower Noric of Garhwal.—In Painkhanda, the Lower Noric is represented by 70 to 100 feet of nodular limestone containing *Proclydonautilus griesbachi*, followed by 200 feet of the so-called " Halorites beds." From the complex of nodular and slaty limestone at the base have been obtained a few badly-preserved cephalopods, of which only one has been found worthy of a specific name ; the following is a list of this unsatisfactory fauna :—

Brachiopoda—
Rhynchonella bambanagensis Bittn.

Cephalopoda—
Proclydonautilus griesbachi Mojs.,
Pinacoceras aff. *imperator* Mojs.,
(*Hauerites*) *metacarnites* sp.,
Arcestes sp.,
Sagenites sp.,
Juvavites sp.,
Parajuvavites aff. *jacquini* Mojs.

The Halorites Beds, on the other hand, include a limestone with a rich fauna of cephalopods, predominantly ammonites, with a few brachiopods and lamellibranchs. The Halorites Beds are composed of black calcareous shales with intercalations of dark limestone, and it is from one of the latter about 180 feet from the base, known as the Halorites Limestone and traceable from Johar to Painkhanda, that the following fossils have been obtained, most of them from the Bambanag cliff where the cephalopods are especially abundant :[1]

Brachiopoda—

Rhynchonella bambanagensis Bittn.

Lamellibranchiata—

Halobia aff. *comata* Bittn.,
Lima serraticosta Bittn.,
Anodontophora griesbachi Bittn.

Cephalopoda—

Halorites sapphonis Mojs.,
,, *procyon* Mojs.,
,, *charaxi* Mojs.,
,, *phaonis* Mojs.,
,, *alcaci* Mojs.,
,, *trotteri* Dien.,
,, *alternans* Dien.,

Anatomites aff. *scissus* Mojs.,

Parajuvavites blanfordi Mojs.,
,, *laukanus* Mojs.,
,, *sternbergi* Mojs.,
,, *feistmanteli* Griesb.,
,, *jacquini* Mojs.,
,, *tyndalli* Mojs.,
,, *renardi* Mojs.,
,, *ludolfi* Mojs.,
,, *minor* Mojs.,
,, *brintoni* Mojs.,
,, *buddhaicus* Mojs.,
,, *stoliczkai* Mojs.,
Thetidites guidonis Mojs.,
,, *huxleyi* Mojs.,
Griesbachites jandianus Mojs.,
Martolites kraffti Dien.,
Tibetites ryalli Mojs.,
,, *murchisoni* Mojs.,
,, *perrin-smithi* Mojs.,
Anatibetites kelvini Mojs.,

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[1] E. V. Mojsisovics. *Pal. Ind.* Ser. XV, Vol. III, pt. 1, 132 (1899) ; C. Diener. *Rec.* XXXIV, 1 (1906).

Cephalopoda—*contd.*

Paratibetites bertrandi Mojs.,
,, *geikiei* Mojs.,
,, *adolfi* Mojs.,
,, *angustisellatus* Mojs.,
,, *tornquisti* Mojs.,
Helictites atalanta Mojs.,
Dittmarites hindei Mojs.,
**Dionites* cf. *asbolus* Mojs.,
Steinmannites desiderii Mojs.,
,, *clionitoides* Mojs.,
,, *noetlingi* Mojs.,
,, *undulatostriatus* Mojs.,
,, *lubbocki* Mojs.,
Clionites woodwardi Mojs.,
,, *salteri* Mojs.,
,, *aberrans* Mojs.,
,, *spinosus* Mojs.,
,, *hughesi* Mojs.,
Sirenites richteri Mojs.,
,, *elegans* Mojs.,
,, *elegantiformis* Dien.,
Sandlingites nicolai Mojs.,
,, *archibaldi* Mojs.,
Arcestes leonardi Mojs.,
**Pinacoceras metternichi* Hauer,
* ,, *parma* Mojs.,
* ,, *postparma* Mojs.,
Bambanagites dieneri Mojs.,
,, *schlagintweiti* Mojs.,
Placites sakuntala Mojs.,
Paranautilus bambanagensis Mojs.,
Indonautilus kraffti Mojs.,
Clydonautilus biangularis Mojs.

From an horizon which appears to correspond to the Halorites Beds, Heim and Gansser have collected an assemblage from the Kalapani area, among which Jeannet has found the following forms additional to those listed above : [1]

Cephalopoda—

Isculites sp.,
Juvavites sp.,
Anatomites cf. *crasseplicatus* Mojs.,
Metasibirites cf. *spinescens* Hauer,
Milites sp.,
Cycloceltites sp.,
Cyrtopleurites herodoti Mojs.,
Proarcestes sp.,
Discophyllites sp.,
Megaphyllites sp.,
Orthoceras sp.

In this locality, *Monotis salinaria* Bronn. was found in the overlying shales.

The fauna of the Halorites Beds is not without affinites with the Middle Noric (Alaunic) of Europe, but the preponderance of Lower Noric (Lacic) elements leaves no uncertainty as to its age. It shows no close affinity with the beds of similar stratigraphical position in Spiti, and the two areas have evidently developed local peculiarities which contrast with the uniformity of the Anisian succession

Both the Halorites Limestone and the older Dolomitic Limestone are wanting in the more eastern sections of this region.

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[1] *Denksch. d. Schweiz. Naturf. Gesells.* Bd. LXXXIII, 111 (1939).

* Found in the Halastatt Limestone of the Alps.

Middle Noric of Spiti and Garhwal.—The lowest sub-stage of the Middle Noric in Spiti lies conformably upon the Lower Noric and consists of calcareous sandstones with plant remains at the base and about 100 feet of limestone above. In places, the latter is full of the remains of crinoids and corals, but this is not a constant feature and the only two fossils so far identified in it are the brachiopods *Spiriferina griesbachi* Bittn. and *Rhynchonella bambanagensis* Bittn. In the Bambanag section of Painkhanda, the place of this sub-stage is filled by 320 feet, of compact, often dolomitic or micaceous limestones, rich in brachiopods and bivalves ; here also *Spiriferina griesbachi* is the characteristic fossil, the complete fauna as known being :

Brachiopoda—

Spiriferina griesbachi Bittn.,
Athyris (*Retzia*) *schwageri* Bittn.,
Athyris (*Spirigera*) *deineri* Bittn.,
Amphiclina sp.,
Rhynchonella bambanagensis, Bittn.,
,, *martoliana* Bittn.,
Aulacothyris joharensis Bittn.

Lamellibranchiata—

Lima cumaunica Bittn.,
Pecten biformatus Bittn.,
,, *interruptus* Bittn.,
Anodontophora griesbachi Bittn.,
Cassianella pulchella Bittn.

The " Coral Limestone " in Spiti is overlain by the " Monotis Beds," consisting of flaggy sandstones alternating with black, splintery, shaly limestones and sandy shales, the total thickness of the succession amounting to about 300 feet ; the following fossils, including the characteristic bivalve, *Monotis salinaria* have been collected from these beds :—

Brachiopoda—

Spiriferina griesbachi Bittn.,
Athyris (*Spirigera*) *dieneri* Bittn.,
Aulacothyris joharensis Bittn.,
Rhynchonella bambanagensis Bittn.

Lamellibranchiata—

Monotis salinaria Schloth. (found also in the Pamirs, at Pishin in Baluchistan in the islands of Borneo and Ceram (Sirang), and in other parts of the world).
Anodontophora griesbachi Bittn.,
Pecten (*Amusium*) *margariticostatus* Dien.,
,, aff. *massolongi* Stopp.,
,, aff. *moniliferus* Muenst.,
Lima cf. *serraticosta* Bittn.,
Pleuromya himaica Dien.

Cephalopoda—

Trachypleuraspidites aff. *griffithi* Dien.

In the Painkhanda area, the equivalents of the Monotis Beds appear to be 130-160 feet of liver-coloured limestones in which *Anodontophora griesbachi* is particularly common ; the only cephalopod found is a fragmentary ammonite belonging to the genus *Sagenites*.

The highest sub-stage in both Spiti and Painkhanda consists of a very characteristic sequence of white and brown quartzites with interbedded limestones and shales, about 300 feet thick in Spiti and 250 feet in the more eastern area. The whiteness of the quartzite bands gives rise to a conspicuous scenic feature and is distinguishable at great distances. In Spiti, three main layers of quartzite can be made out, the limestone intercalations occurring in the lower part of the sequence and the black shales towards the top. The characteristic fossil is *Athyris maniensis* v. Krafft. and is restricted to this horizon. The fauna of the quartzite beds is as follows :—

Spiti.

Brachiopoda—
Spirigerina griesbachi Bittn.,
Spirigera (*Athyris*) *maniensis* v. Krafft,
,, (?) *maniensiformis* Dien.,
Aulacothyris joharensis Bittn.,
Rhynchonella bambanagensis Bittn.

Lamellibranchiata—
Pecten aff. *moniliferus* Muenst.,
Lima cf. *serraticosta* Bittn.,
,, aff. *cumaunica* Bittn.,

Painkhanda.

Brachiopoda—
Athyris (*Spirigera*) cf. *noetlingi* Bittn.,
,, ,, *dieneri* Bittn.,
Aulacothyris joharensis Bittn.

Lamellibranchiata—
Pecten interruptus Bittn.

Lower and Middle Noric of Byans.—The detailed correlation of the beds immediately following the Tropites Limestone in Byans is a little obscure, but there are 1,000 feet of greenish black shales with sandy bands, which, there is good reason to believe, correspond more or less to the Lower and Middle Noric, especially, as they are followed by the Megalodon Limestone, a bed found both in Spiti and in Painkhanda. In them the genus *Arcestes* has been identified, but most of the ammonites are indeterminable.

Upper Noric.—In Spiti, Painkhanda and Byans, the Middle Noric is succeeded by a great thickness of well-bedded limestones and dolomites, too uniform for lithological subdivision and too poor in fossils for any detailed faunistic subdivision. This sequence constitutes the Kioto Limestone. In Spiti there are about 2,300 feet of these beds, the uppermost portion of which includes a band with Middle Jurassic fossils. At about 930 feet from the base, *i.e.*, from the Middle Noric quartzite, specimens of *Spiriferina* cf. *obtusa* have been collected and are thought to indicate a Liassic age. It may be assumed, therefore, that a little over 900 feet of these limestones and dolomites represent the uppermost horizons of the Trias and the whole of the Rhaetic ; Rhaetic fossils are entirely absent, but Upper Triassic types have been found at two horizons, one about 50 feet up from the base and the other between 200 and 300 feet above the same datum-line. In the lower of these two horizons—a limestone some 20 feet thick—have been observed immense numbers of *Megalodon ladakhensis* Bittn. and *Dicerocardium himalayense* Stol. ; this is Stoliczka's "Para Limestone", a very characteristic rock when polished by ice or running water, sections of the two bivalves preserved in calcite standing out clearly in fantastic patterns from the dark grey matrix.[1] In the upper horizon the following have been identified : *Athyris noetlingi* Bittn., *Spiriferina* cf. *haueri* Suess, *Lima cumaunica* Bittn., *Pecten chabrangensis* Dien., *P.* aff. *landranus* Bittn., *Pecten* (*Entolium*) cf. *subdimissus* Muenst. and *Megalodon ladakhensis* Bittn. A white dolomitic band, 30 feet thick, is a conspicuous feature in several sections but has yielded no fossils.

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[1] C. Diener. *Mem.* XXXVI, pt. 3, 99 (1912).

In Painkhanda there is the same lack of boundaries. Between the Middle Noric quartzite and a zone of thin-bedded limestones with many bivalves of Liassic affinites, occurs a mass of limestone, 1,800 to 2,000 feet in thickness, which must represent the Upper Noric and Rhaetic; this limestone has yielded sections of *Megalodon* even in its topmost layers but the species is indeterminable.

The same thick limestone sequence is found in Byans, straddling the Upper Noric and practically the whole of the Jurassic including the Rhaetic, and overlain by the Spiti Shales (Upper Jurassic or Neocomian); the basal portion is the Megalodon Limestone of the other localities.

NEPAL.

That the fossiliferous Trias extends into Nepal is probable from the Triassic affinites of two fossils from Mukhtinath, north of crystalline peaks, *Halobia* cf. *charleyana* Mojs. and *Ptychites* sp. (section *rugiferi*).[1]

EXOTIC BLOCKS FROM TIBET.

To the northeast of Milam, in the old Malla Johar district and the adjoining portion of Tibet, a facies of the Trias differing lithologically and, so far as the Upper Triassic is concerned, faunistically, from that characterising the belt just described, occurs in certain exotic blocks which, it is surmised, have come from some locality further north. The mode of occurrence and origin of the latter will be discussed in the final chapter on the Himalaya. Some of these blocks belong to various stages of the Trias.

The Lower Trias is represented in a block near the Kiogarh-Chitichun Pass (17,900 feet), one labelled No. 20 on Dr. Krafft's map;[2] the fossils therefrom include the following indifferently preserved cephalopods :—

" *Meekoceras* " *joharense* v. Krafft (predominant form),[3]
,, *infrequens* v. Krafft,
,, *jolinkense* v. Krafft,
" *Xenodiscus* " (? *Anakashmirites*) cf. *nivalsi* Dien.,
Hedenstrœmia cf. *byansica* v. Krafft.

The fauna is that of the Lower Trias of Spiti and Painkhanda, but the rocks differ lithologically and comprise thin-bedded, earthy limestone, dark red in colour with a few grey layers.[4] In the Chitichun (Chirchun) area there are no blocks of this age.

Blocks of Anisian age show the same lithological contrast with the Spiti and Painkhanda rocks. The " Middlemiss Crag " for instance, east of " Chitichun No. 1 " is made up of several blocks of red, or red and white limestone; surrounded on all sides by crushed and disturbed Spiti Shales, and including occasional layer of a red crinoidal limestone which has yielded some very small gastropods and bivalves and the following fauna :[5]

**Ceratites* (*Danubites*) *kansa* Dien.,
,, ,, *ambika* Dien.,
" *Sibirites* " *pandya* Dien.,

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[1] C. Diener. *Mem.* XXXVI, pt. 3, 150 (1912).
[2] A. Von Krafft. *Mem.* XXXII, 14 (1902).
[3] According to Dr. L. F. Spath, the genus *Meekoceras senus stricto* does not occur in India.
[4] A. Von Krafft. *Mem.* XXXII, 141 (1902).
[5] As before, Dr. Spath's emendations are given in square brackets..
* Spiti and Painkhanda forms.

***Monophyllites confucii* Dien.,
* ,, [*Leiophyllites*] *pradyumna* Dien.,
,, [*Leiophyllites*] *pitamaha* Dien.,
* ,, (*Ussurites*) *hara* Dien. [***Eophyllites*** *refractus* Spath.]
* ,, (*Ussurites*) *kingi* Dien. [***Ussurites*** (?) ***decipiens*** Spath],
Procladiscites yasoda Dien.,
Xenaspis [? *Leiophyllites*] *middlemissi* Dien.,
**Japonites ugra* Dien.,
Sturia mongolica Dien.,
Orthoceras sp.

This fauna is very close to the zone of *Spiriferina stracheyi* and like it, shows no marked affinities with the Mediterranean equivalent. Two other blocks belonging to the same horizon have been recorded in the Chitichun region, one in the low pass west of "Chitichun No. 1" and the second north of Lochambel-ki-chak, near the pass leading into the Chaldu valley.[1]

The dark red, highly ferruginous limestone of Exotic Block "No. 1" south east of the peak of Balchdhura II, has yielded *Daonella indica* Bittn. and *Halobia* sp. and may represent the Lower Carnic or perhaps the Ladinian.

An exotic block of Carnic age, with the ammonite *Jovites* aff. *bosnensis* Mojs.[2] composed of red marble, has been found near Sangcha Talla camping ground.

Two blocks of Middle or Upper Carnic age have been noted in Malla Johar. One of these, a very small one near Mall Kiogarh camping ground, "No. 5" of Dr. Von Krafft's list, consists of much-altered red limestone, with fragments of *Carnites* sp. and *Proarcestes* aff. *ausseanus* Hauer. From "No. 2" a bright red marble almost indistinguishable from that of the Halstatt limestone, situated about a mile northwest of Balchdhura, has been collected the richest fauna of all the blocks :—

Gastropoda—
Loxonema (*Polygirina*) cf. *elegans* Hoern.,
Sagena cf. *geometrica* Kok.,
Capulus (*Phryx*) *joharensis* Dien.,
Naticopsis aff. *obvallata* Kok.

Cephalopoda—
Dictyoconnites aff. *haueri* Mojs.,
Proclydonautilus triadicus Mojs.,
,, *buddhaicus* Dien.,
Grypoceras suessiforme Dien.,
Mojsvaroceras aff. *turneri* Hyatt & Smith,
Cladiscites crassestriatus Mojs..
,, cf. *gorgiae* Gemm.,
,, cf. *coracis* Gemm.,
,, cf. *pusillus* Mojs.,
Hypocladiscites subcarinatus Gemm.,
,, *subaratus* Mojs.,
Arcestes periolcus Mojs.,
,, cf. *richthofeni* Mojs.,
,, aff. *decipiens* Mojs.,
,, cf. *placenta* Mojs.,
Proarcestes gaytani Klipst.,
,, cf. *ausseanus* Hauer.,
,, aff. *barrandei* Lbe.,
Discophyllites floweri Dien.,

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[1] C. Diener. *Mem.*, XXXVI, 134 (1912).

[2] Spiti and Painkhanda forms.

Cepholopoda—*contd*.
Pinacoceras aff. *rex*. Mojs.,
Placites cf. *perauctus* Mojs.,
Discotropites cf. *sandlingensis* Hauer.,
Tropites cf. *subbullatus* Hauer.,
,, aff. *acutangulus* Mojs.,
,, aff. *wodani* Mojs.,
Anatropites cf. *spinosus* Mojs.,
,, *pilgrimi* Dien.,
Margarites irregularicostatus Dien.,
Jovites cf. *spectabilis* Dien.,
,, *daciformis* Dien.,
Juvavites kraffti Dien.,
,, *dogranus* Dien.,
,, aff. *subinterruptus* Mojs.,
Griesbachites pseudomedleyanus Dien.,
,, cf. *kastneri* Mojs.,
Anatomites aff. *camilli* Mojs.,
,, aff. *henrici* Mojs.,
,, aff. *crasseplicatus* Mojs.,
Gonionotites cf. *italicus* Gemm.,
Tibetites bhotensis Dien.,
Aulacoceras cf. *timorensis* Wanner.[1]

In this block are the homotaxial equivalents of both the Middle and Upper Carnic and their affinites with the Alpine development of these subdivisions are in fact closer than they are with the Spiti and Painkhanda assemblages. Lithologically, the resemblances to the red Halstatt marble are so marked that the two rocks are almost indistinguishable; with the dark shales and limestones of Spiti and Painkhanda there is no resemblance. *Arcestes* and *Cladiscites*, two genera which are rare in the Carnic of Spiti and Painkhanda, preponderate in the exotic block "No. 2" while no less than 19 species in the latter are identical or probably identical with forms in the Mediterranean province.

A conical block (Block 8) of yellowish grey dolomitic limestone to the east of Chitichun 1, is like the rock forming the upper beds of the Upper Trias of the Shalshal cliff further south, but has yielded no fossils.

SOUTHERN TIBET.

In view of the eastward thinning of the Trias when traced from Spiti through Painkhanda into Byans, it is interesting to find indications of this system, doubtful though they are, in that small tongue-like projection of Tibet which extends southwards between Sikkim and Bhutan. Here, to the south of Phari Dzong, crops out the Dothak series of Hayden, cut off to the west by the large fault which coincides more or less with the Ammo Chu, and by it separated from the submetamorphic Khongbu series. On the south, the Dothak exposure is in contact with the Chumbi granite, the sediments along the boundary showing evidence of contact-metamorphism; to the north, the curved belt of the Dothaks dips under the Jurassics of the Phari plain.

The beds consist of limestone, which predominates and forms steep cliffs at Dothak and in the neighbouring ridges, and in addition sandstone, quartzite, slate and shale.[2] Since the series is several thousands of feet in thickness and, like the Kioto Limestone of Spiti, extends up into beds believed to belong to the Lias, it very probably includes beds of Triassic age and perhaps part of the uppermost Palaeozoic. Casts of ammonites in a thin band of quartzite and a few fragments of bivalve shells in an indurated slate, near the middle of the group, are the only fossils so far found; all of them proved to be generically indeterminable.

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[1] *Denkschs. d. Schweiz. Naturf. Gassells.* Bd. LXXIII, Abt. 1 p. 150 (1939).

[2] *Mem.* XXXVI. Pt. 3, 20-21 (1907).

Some distance to the west of this exposure, the Trias is probably again represented in the snowy range which runs from Chomiomo (Chomoyumo) westwards to the Nepalese frontier and forms the northern boundary of the Lhonak valley. In streams flowing into the Yaru, boulders of dark grey limestone have been observed much resembling the Kioto Limestone of the more western parts of the Himalaya, but have so far yielded no fossils.

MOUNT EVEREST AREA.

A limestone series, occurring disconnectedly between the crystalline complex of Mount Everest and Gaurisankar (Chomo Tsering) and a thick shale formation the bulk of which is Jurassic in age, was at first thought by Dr. Heron to be the approximate equivalent of the Kioto Limestone of the Zanskar range, and was mapped with a query as Permo-Trias.[1] As we have seen, it is doubtful whether these beds range above the Permian, in which case the Trias, if present in this area, must be represented by the lower portion of the great shale formation, up into which the limestones pass.[2]

SIKKIM.

On the eastern side of Lachi hill and near the northern end of the Tso Lhamo and therefore north of the Great Himalaya crest-line, Messrs. Auden and Gourlay found dark limestones and shales containing a rich fauna of ammonoids, lamellibranchs and brachiopods. As a result of a preliminary examination of this fauna, Dr. M. R. Sahni has assigned it to the Middle Trias, and has identified the following:[3]

Brachiopoda—

- *Dielasma himalayanum* Bittn.,
- *Retzia schwageri* Bittn.,
- *Rhynchonella* sp.

Lamellibranchiata—

- *Daonella* sp.,
- *Lima* sp.,
- *Pecten* sp.,

Cephalopoda—

- *Ceratites* (*Paraceratites*) *trinodosus* Mojs.,
- ,, ,, aff. *thuillieri* Oppel.,
- *Ptychites* aff. *sumitra* Dien.,
- *Beyrichites* (at least two new species).

Underlying the richly fossiliferous beds are 300 feet of grey, gritty flags containing dubious plant remains. The whole series, for which Auden has proposed the provisional name of Tso Lhamo series, follows the Lachi beds (Permian) of Wager in stratigraphical sequence.[4]

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[1] *Rec.* LIV, Pl. 8 (1922).
[2] *Ibid.* p. 232.
[3] *Gen. Rep.*, *Rec.* 72, 21 (1937).
[4] *Rec.* LXIX, 152 (1935).

KASHMIR.

Vihi area.—Some interesting exposures of the Trias in the Vihi district of Kashmir, to the east of Srinagar, which have been described by Middlemiss and Bion, correlate closely, in respect of their lower portions, with the central Himalayan subdivisions. Hills of Upper Trias rise from the Vihi plain and cover a large circular area north of Wastarwan peak. This Upper division is separated from the Panjal Volcanics by a thin band composed of Middle and Lower Trias overlying Productus Shales and Zewan beds (Permian), the narrow composite outcrop curving in an incomplete circle or horse-shoe open towards the Jhelum river on the southwest, through the villages of Mandakpal, Pastannah, Lam, Narastan, Nagbaran and Khunmu; within the horse-shoe an inlier of Anisian projects from the alluvium at Khrew (Khreuh).

The Lower Trias is poorly exposed, the best sections occurring at Pastannah and Nagbaran. In the latter area, on the northeastern side of the horse-shoe the *Otoceras* zone was discovered by Bion. It occurs in a layer of calcareous nodules 20 feet above the base of the black shales which are assumed to initiate the Lower Trias. From it have been collected many specimens of *Otoceras* and almost all the other members of the Himalayan *Otoceras* fauna.[1] The *Ophiceras* zone has also been recognised some 30 feet above that of *Otoceras* at Nagbaran. In this locality the black shales pass up, by a gradual increase in the number of calcareous intercalations, into about 300 feet of thin-bedded, blue limestone, which almost invariably weather into two well-marked crags; the lower of these is barren of fossils but the upper, which contains subordinate shales, has yielded an assemblage which is very close to the "*Meekoceras*" zone of the Central Himalaya.

At Pastannah, the Lower Trias consists of at least 300 feet of dark grey, compact limestone, exactly similar lithologically to the corresponding rock at Painkhanda, and especially fossiliferous throughout some 50 feet of its sequence. The genus *Otoceras* has not yet been found in this area, but the lowest horizons of the Trias are largely hidden by débris and further search may be more successful. The *Ophiceras* zone of the Himalaya is present and has much the same fauna; *Xenodiscus*, however, predominates over *Ophiceras*, though there are forms which are transitional between those two closely allied genera. The lamellibranch *Pseudomonotis*, is found in large number, often on the same slab of rock as the ammonoids. The fauna is undoubtedly Lower Werfen (Lower Bunter) as shown below, though perhaps more than one zone is represented.[2]

Lamellibranchiata—
Pseudomonotis (Claraia) griesbachi Bittn.,
,, ,, *aurita* Hauer (found in Alps),
,, ,, *painkhandana* Bittn.,
,, (*Eumorphotis*) *tenuistriata* Bittn. (found in Bokhara),
,, ,, *multiformis* Bittn. (found in Vladivostok and in Bokhara),
,, ,, aff. *austriaca* Bittn. (species found in the Alps).

Cephalopoda—
Xenodiscus [*Glyptophiceras*] *himalayanus* Griesb. [*Glyptophiceras pascoei* Spath],
,, cf. *lissarensis* Dien. [*Glyptophiceras kashmiricum* Spath],

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[1] *Gen. Rep.*, *Rec.* XLIV, 39 (1914).

[2] Dr. Spath's emendations in square brockets.

Cephalopoda—*contd.*
Xenodiscus [*Glyptophiceras*] *aequicostatus* Dien.,
,, [*Glyptophiceras*] *althothae* Dien.,
,, *salomoni* Dien.,
,, cf. *ellipticus* Dien.,
,, *comptoni* Dien.,
,, [? *Xenodiscoides*] cf. *rotula* Waag. (species found in the Salt Range),
,, cf. *ophioneus* Waag. [*Glyptophiceras ophioides* Spath],
,, cf. *sitala* Dien.,
Ophiceras [*Lytophiceras*] *sakuntala* Dien.,
,, [*Lytophiceras*] *ptychodes* Dien.,
,, [*Lytophiceras*] *chamunda* Dien.,
,, [*Metophiceras*] *demissum* Dien.,
,, cf. *gibbosum* Griesb. [? *Acanthophiceras*],
,, cf. *tibeticum* Griesb.,
,, cf. *medium* Griesb.,
Inyoites [*Subinyoites*] *kashmiricus* Dien. [horizon doubtful],
Vishnuites pralambha Dien.,
Pseudosageceras clavisellatum Dien.,
Orthoceras sp.

The "*Meekoceras*" zone has also been identified at Pastannah, containing a similar fauna to that found at the same stratigraphical level in the Guryul ravine (see below).

At Narastan there is a continuous section from the sandy Productus Shales up into the thin-bedded, dark grey, Lower Triassic limestones, which are similar lithologically to the Pastannah rock and higher up contain numerous traces of ill-preserved ammonoids; the genus *Ophiceras* has not been recognised here. The Lower Trias is doubtfully exposed at Lam.

A fauna of Lower Triassic age, collected from the Guryul ravine near Khunmu and to a limited extent from Mandakpal, was assigned by Diener to the Hedenstroemia Beds, and to the "*Meekoceras*" zone by Middlemiss. Probably more than one zone is represented and the presence of *Kashmirites* seems to indicate the Upper Owenitan. In the Guryul ravine, these fossils occur in a coarse, dark grey, semi-crystalline limestone, occasionally rich in crinoid stem remains and include the following:

Lamellibranchiata—
* *Pseudomonotis* (*Claraia*) *decidens* Bittn.
Cephalopoda—
**Flemingites* sp. (group of *flemingianus*),
,, cf. *muthensis*. Krafft,
"*Meekoceras*" aff. *jolinkense* Kr. & Dien.,
* ,, (*Koninckites*) cf. *yudishthira* Dien. [? *Pseudaspidites*.]
,, (*Aspidites*) sp., (group of *kingianus*),
Pseudosageceras sp.,
Prionites guryulensis Dien.,
Sibirites kashmiricus Dien. (genus found in the Hedenstroemia beds),
Sibirites aff. *ibez* Waag. (Mandakpal only),
Kashmirites blaschkei Dien.,
,, *subarmatus* Dien.,
,, aff. *laevigatus* Waag.,
Stephanites aff. *superbus* Waag.,
Nanuites sp.

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* Forms from the Hedenstroemia Beds of Spiti and Garhwal in which also occurs the genus *Sibirites*.

The Middle and Upper Trias are well exposed in a long line of precipitous scarps, the former passing up into the latter. The lowest beds in all sections comprise 300-500 feet of buff-coloured, unfossiliferous, sandy limestones inter-bedded with shales, and in all probability represent the Lower Anisian, though no trace of a Lower Anisian fauna has yet been found.

The Upper Anisian is exposed at Pastannah and at a locality a mile to the west thereof, at the Khrew inlier in a Triassic exposure, two miles north of Barus, at Khunmu, and at Lam, but is hidden at Narastan. The following copious and aggregate fauna has been identified by Professor Diener, and probably includes the two upper Anisian zones of *Paraceratites binodosus* and *P. trinodosus*. *Spiriferina stracheyi*, a form characteristic of the top of the Lower Anisian in the central Himalaya, is found here in the Upper, ranging throughout this subdivision into the Carnic stage above :—

Brachiopoda—
  Spiriferina stracheyi Salt.,
  Mentzelia cf. *koeveskalliensis* Suess.,
  Dielasma himalayanum Bittn.,
  Rhynchonella trinodosi Bittn.,
    ,, *mutabilis* Stol.,
    ,, *lamana* Dien.,

Lamellibranchiata—
  Myophoria aff. *laevigata* Ziet.,
    ,, (group of *carinatae*),
  Pleurophorus aff. *curioni* Hauer.,
  Modiola sp.,
  Arcoptera indica Dien.,
  Perna aff. *vetusta* Goldf.,
  Avicula pastannahensis Dien.,
  Lima sp. (group of *striatae*),
    ,, aff. *subpunctata* d'Orb.,
  Mysidioptera eximia Dien.,
  Pecten sp.,
  Anomia triadica Dien.,
  Anodontophora patarkulensis Dien.,
  Lithophagus sp.,

Gastropoda—
  Worthenia dharmaensis Blaschke.
  Promathildia sp.,
  Euomphalus sp.,
  Marmolatella sp.,
  Scurria sp.,
  Conularia sp.,

Nautiloidea—
  Mojsvaroceras kagae Dien.,
    ,, aff. *nivicola* Dien.,
  Thuringionautilus sp.,
  Syringonautilus aff. *carolina* Mojs.,
  *_Grypoceras vihianum_ Dien.,
  *_Paranautilus kashmiricus_ Dien.,
  Orthoceras cf. *campanile* Mojs.

Ammonoidea—
  Ceratites [*Paraceratites*] *thuillieri* Opp.,
    ,, [? *Paraceratites*] cf. *trinodosus* Mojs.,
    ,, [? *Paraceratites*] aff. *binodosus* Hauer.,
    ,, *kuvera* Dien.,
    ,, *truncus* Opp.,
    ,, aff. *superbus* Mojs.,
    ,, [? *Semiornites*] aff. *dalcifer* Hauer.,
    ,, (*Hollandites*) *voiti* Opp.,

Ammonoidea—*contd.*

Ceratites [*Hollandites*] *ravana* Dien.,
  ,, ,, *dungara* Dien.,
  ,, ,, cf. *arjuna* Dien.,
  ,, ,, *vyasa* Dien.,
  ,, aff. *cecilii* Dien.,
  ,, (? *Hollandites*) *onustus* Opp.,
  ,, (*Halilucites*) sp.,
Beyrichites khanikofi Opp.,
  ,, *kesava* Dien.,
Sibirites cf. *prahlada* Dien. (see parenthesis on p. G. 262),
**Proteites indicus* Dien.,
Acrochordiceras (*Epacrochordiceras*) cf. *enoda* Hauer,
  ,, cf. *haueri* Arth.,
  ,, cf. *balarama* Dien.,
**Isculites middlemissi* Dien. (the largest species of this genus),
Smithoceras herminae Dien.,
Pinacoceras cf. *loomisi* Dien.,
Ptychites sahadeva Dien.,
  ,, *brueckneri* Dien.,
  ,, *cunninghami* Dien.,
  ,, *barclayi* Dien.,
Gymnites jollyanus Opp.,
  ,, *sankara* Dien.,
  ,, *vasantasena* Dien.,
  ,, cf. *kirata* Dien.,
Buddhaites rama Dien.

Of the specifically determined cephalopoda, all except four (asterisked) have been found in either Spiti or Garhwal or both. Notable features are the restriction of the genus *Gymnites* to the lower, and of the genus *Ptychites* to the higher horizons, and the indiscriminate distribution of the leading species of *Ceratites*—especially of *C.* (*Paraceratites*) *thuillieri*—throughout the subdivision; *Gymnites* and *Buddhaites* preponderate in numbers, while *Ptychites* is comparatively scarce and represented by the group of *megalodisci* only; in Spiti and Painkhanda this genus, although attaining its maximum development in the topmost beds, is distributed throughout the whole of the Upper Anisian and is remarkably rich in forms, especially in numbers of species and individuals of the *megalodisci*. Unlike the Upper Triassic fauna of the central Himalaya, lamellibranchs are richly represented in numbers in the Kashmir assemblage.

In all sections the Middle Trias passes up gradually into the more massive beds of the Upper Trias which is several thousands of feet in thickness. These beds which cover a much wider area than the Lower and Middle Trias, consist of pale grey limestone and dolomite with only occasional quartzite layers, and in some places pass upwards into dark slates and thin limestones probably of Lower Jurassic age. The Upper Triassic limestones and dolomites build the magnificent cliff which characterise the numerous river gorges of this region.

The rich cephalopod faunas, the Daonella Shales, the Halobia Limestone and the Megalodon Limestone of the Spiti and Kumaon Himalayan region are all unrepresented in this part of Kashmir, and the fossils so far found nearly all come from the lower portion of the subdivision where beds rich in lamellibranchs and brachiopods are occasionally met with. These bivalves indicate a Carnic age close to that of the St. Cassian and Raibl bed of the Alps. The least scanty assemblage comes from Pastannah, derived from four horizons :—

Brachiopoda—
- *Dielasma julicum* Bittn.

Lamellibranchiata—
- *Myophoria* cf. *kefersteini* Muenst., var. *multiradiata* Waag.,
  - ,, *middlemissi* Dien.,
  - ,, aff. *whateleyae* Buch.,
- *Trigonodus* sp.,
- *Hoernesia bhavani* Dien.,
- *Pseudomonotis* sp.,
- *Lima* cf. *subpunctata* d'Orb.,
- *Mysidioptera* sp.,
- *Pecten* (*Chlamys*) *middlemissi* Dien.,
  - ,, (*Velopecten*) sp.

Beds which, from their stratigraphical position, must belong to the Upper division of the Triassic system, have yielded a few odd fossils at Khrew, Lam and Narastan. Among the brachiopods Anisian types predominate, but the meagre faunas afford little assistance in deciding the precise age of the beds. They are as follows :—

Khrew . .	*Spiriferina stracheyi* Salt., ,, aff. *lilangensis* Stol., *Mentzelia mentzeli* Dunb., *Rhynchonella trinodosi* Bittn., var. *freshfieldi* Dien., *Hœrnesia bhavani* Dien.,
Lam . . .	(*b*) *Spiriferina stracheyi* Salt., *Gervillia* sp., (*a*) *Trigonodus* sp., *Pleurophorus* cf. *curioni* v. Hauer.
Narastan . .	*Spiriferina stracheyi* Salt., *Rhynchonella lamana* Dien.

Palgam outcrop.—East of the Vihi area, a small patch of Permian, Lower Middle and Upper Trias, surrounded entirely by Panjal Trap, is exposed in the upper Lidar valley around Palgam. The *Otoceras* zone, with many specimens of that genus and nearly all the other members of that fauna, has been located by Bion in a layer of calcareous nodules ; a surprising feature in this example of the fauna is the presence of species of *Productus*.[1]

Islamabad belt.—The Upper Trias has been mapped by Middlemiss as cropping out in a broad belt from the alluvium east of Islamabad.

Exposures east and west of the Wular lake.—Disconnected patches of Trias, mostly of the Upper division, have been mapped by Bion to the east of the Wular lake, one of considerable size and all of them in contact with or surrounded by Panjal trap. Some of these have already been described in the section on the Panjal Volcanics, since there is reason to believe that the deposition of the Triassic limestone was in places an incident which took place in the Panjal Trap period during a lull in the extrusion of lava. In the Erin stream-course, for instance, the base of the Upper Trias is interbedded with the traps and if the boundary is traced southeastwards successive belts of Middle Trias, Lower Trias and Permian beds make their appearance in normal sequence between the trap and the Upper Trias. In the small patch at Ambersilwar, west of the Wular lake, the Triassic limestone is both underlain and overlain by traps of the Panjal suite; there is a gradual passage from the trap beneath into the limestone, the base of which is full of ashy material.[1] The upper portion of the Panjal Trap must in places be regarded as belonging to the Triassic period.

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[1] *Genl. Rep. Rec.* XLIV, 39 (1914).

Sonamarg-Gurais belt.—A large, irregular, NW-SE belt of rocks consisting mostly of the Kioto limestone, but including the Lower Trias and Anisian, stretches from the Bhot Kol Pass, about fifty five miles east of Srinagar, across the upper Sind valley, past the Zoji La, through the hill-station of Sonamarg, and across the Kishenganga river through Gurais to a point a few miles N. N. E. of Kanzalwan. It forms part of the Great Himalaya and encloses an inlier of older rocks. The country occupied by it is not only high but precipitous, and through it the Kishenganga has cut a deep valley obliquely across the strike; at Gurais the outcrop is seven miles wide. A good section is also seen in the upper Dras valley which traverses much of the sequence. The Kioto limestone is, as elsewhere, several thousands of feet in thickness and consists almost entirely of evenly-bedded, dark grey, occasionally ochreous limestones, which are much folded and contorted. Small thicknesses of black slates and jasper-like quartzite have been noted at two or three places, as well as a few oolitic beds and some limestone breccia. The bulk of the limestone is unfossiliferous, but in the lower part, in the Gurais section, there are a few beds with much crushed fossils, among which are: broken valves of *Myophoria*, a single valve impression of *Trigonia* sp., two species of *Dielasma* (*D.* aff. *julicum* and *D. himalayanum*), numerous examples of *Naticopsis* and *Marmolatella*, casts of one or two species of large thick-valved *Megalodon* and *Dicerocardium*, doubtful examples of *Trigonodus*, *Pseudomonotis*, *Spiriferina* and *Rhynchonella*, numerous corals including *Calamophyllia*, and one or two specimens of a large *Thecosmilia*; the most plentiful remains are those of crinoid stems. A *Myophoria* from an impure calcareous rock in the Dras valley is allied to *M. ovata*, a form found in but not restricted to the Werfen beds of the Alps; its presence indicates either Lower Trias or Anisian. The presence of the Upper division of the Anisian is shown by the collection of *Ceratites* [*Paraceratites*] *thuillieri* Opp. (from Sonamarg) and *Proarcestes balfouri* Opp. [*P. escheri* Mojs.] from Dras. The rich cephalopod faunas of other regions have not been observed in this belt. At Gurais the Upper Trias, with species of *Myophoria*, *Trigonia*, *Dielasma*, *Marmolatella* and *Megalodon*, together with some corals and crinoids, rests with no discordance upon the Panjal Trap, the uppermost flows of which may thus belong to older portions of the Upper Trias. Between Tragbal and Gurais, thick intercalations of Middle and Lower Trias are seen in the traps[2] and between Khapuri and the Kissar peak (14,218 feet) the trap and ash beds are described as passing up into the overlying limestones which are crowded with pyroclastic dèbris.[3] In the Gamru valley at Matayan, Dr. De Terra found the commonest fossil to be *Megalodon ladakhensis* Bittn., the index fossil of the Noric and Rhaetic of Spiti and Kashmir, and collected in addition species of *Thamnastroea* and *Rhynchonella*. The Trias of this valley is described as at least 7,000 feet thick and as forming a WNW-ESE syncline, perhaps an outlier of the great Triassic syncline of Spiti.[1] The Anisian is thought to be represented here by thin-bedded limestones and shales below the massive limestones of the Upper Trias. Between Matayan and Pindras, the Triassic limestone is sharply compressed into recumbent folds; one section near Matayan shows a well-developed recumbent fold resting on Panjal traps.[2] From this neighbourhood, *i.e.*, the southern flank of the Dras valley, the following fossils have been identified by Sign. C. F. Parona, and probably indicate the Upper Division of the Trias[3]:

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[1] D. N. Wadia. *Rec.* LXVIII, 168 (1934).

[2] D. N. Wadia. *Rec.* LXVIII, 161 (1934).

[3] *Gen. Rep. Rec.* LXIX, 61 (1935).

Algae—
- *Solenopora* cf. *triassina* Vin.,

Actinozoa—
- *Balatonia* cf. *kochi* Vin.,
- *Myriophyllia münsteri* Volts,
- *Astroemorpha confusa* Winkl., var. *major* Vin.
- *Montlivaltia* sp.

Crinoidea—
- *Encrinus* sp.

The section across Sonamarg to Zoji La has been described by Middlemiss. The Panjal Trap is followed without change of dip by 600 feet of imperfectly exposed, deeply-eroded, pale, sandy and schistose slates or phyllites; since no fossils have been found in them, it is not known whether any of them belong to the Gondwana, the Zewan, Productus Shales, or the Lower Trias. The Anisian, however, has been recognised in the 200 feet of the phyllites and ochreous calcareous bands which immediately succeed; the fossils in these rocks have nearly all been obliterated by folding, but one specimen of *Ptychites* and numerous fragments of other ammonoids and gastropods have been recognised. Next come about 400 feet of black shales, followed by the Upper Triassic massive limestone which continues up the Sonamarg valley to Baltal (altitude 10,000 feet), with occasional crinoid and coral remains. Towards the Zoji La, these massive limestones give place to thinner-bedded limestones, interbedded with black shale or much crushed, fissile, pyritous slate; in the more calcareous layers nearer the pass are black lumps suggestive of ammonoids as well as other more definitely recognisable though distorted ammonoid remains. These beds are thought to represent the Middle Trias reduplicated again and again by inverted folding and faulting.[4]

Northeast of the above wide (Sonamarg-Gurais) belt, two or three highly eroded outliers of limestone lying in the Salkhala slates were at first mapped as Eocene. That lying furthest to the northeast and carrying the village of Kamri, however, consisting of a recrystallised grey limestone, differs lithologically from the others and has yielded traces of fossils, including crinoid stems and a coral resembling *Calamophyllia*. The latter suggests an upper Trias age, and is found in rocks of this epoch around Gurais and Vihi.[5]

Shamsh Abari syncline.—The minute patch of Trias in the core of the Shamsh Abari syncline, to the west of Hardwar, is interesting in that it consists of the same limestone as that of the Upper Trias at Gurais and the Wular lake vicinity, with black siliceous slates at the base; these beds lie directly imposed upon the highest beds of the Panjal Trap.[6]

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[1] *Mem. Connect. Acad.*, VIII, Art, II, 29 (1935).
[2] J. B.. Auden. *Rec.*, LXIX, 125 (1935).
[3] *Atti d. R Accad. d. Sci. d. Torino*, LXVII, 179 (1932).
[4] *Rec.* XLI, 142 (1911).
[5] D. N. Wadia. *Rec.* LXVIII, 420 (1934).
[6] H. S. Bion. *Rec.* LXVIII, 161 (1934).

Zanskar basin.—Of the main mass of the Trias in Kashmir, lying on the Tibetan side of the Great Himalaya, we have but scanty information. It forms a broad belt, continuous with the Trias of Spiti, through western Rupshu along the Tsarp or upper Zanskar valley, by a lower section of which river it is traversed, to about a dozen miles east of Kartse.[1] In general, it overlies the Kuling Shales and is accompanied by younger beds. The rocks for the most part consist of a great thickness of limestones and dolomites, in places highly contorted, belonging to the Upper division of the Trias; Rhaetic and perhaps higher Jurassic horizons may also be represented in this so-called "Kioto Limestone." At Mulbekh in the upper Wakka valley, southeast of Kargil, there is an isolated mass of Triassic limestone exposed, containing numerous fragmentary fossils with *Megalodon* as the commonest type; De Terra suggests that this is a down-faulted portion of the adjoining Triassic sequence. A similar occurrence is recorded in Zanskar range near the Namika Pass.[2] From the northern edge of the main outcrop of Trias near Bed Karbu, De Terra has collected *Thecosmilia*, *Rhabdophyllia* and *Lovcenipora*, from a fallen block.

Among the Mesozoic rocks which occupy most of the high ranges between Spiti and Rupshu, the coral limestone of the Upper Trias forms a conspicuous and useful stratigraphical feature.[3] In Rupshu, especially, it takes the form of a white dolomite, retaining its numerous corals. In the beds below this dolomite, metamorphism has obliterated as a rule all traces of fossils. The Trias is well exposed in the Pangpo, Para and Chepzi valleys, consisting of crushed limestones, slates and calc-schists. Among them representatives of the Middle and Lower Trias as well as of the Permian, can be definitely recognised, not only by lithological sequence, but by rare badly-crushed fossils in the Pangpo river near Kiangshisa and in the Para river near Setang Gongma. In the former the Ladinian stage of the Trias is represented by black, calcareous slates with *Daonella indica*. The lateral valleys of the Tsarap have yielded the Anisian form *Spiriferina stracheyi*. The presence of the Upper Anisian is further indicated by the presence of *Ptychites durandi* Dien, (from Padam) and *Gymnites salteri* Beyr. (from some unknown locality in Ladakh). From Ladakh an ammonoid collected by Prochnow has been referred by Waagen to *Flemingites*, an indication of the presence of the Lower Trias. Three Noric fossils have been specifically determined: *Athyris* (*Spirigera*) *noetlingi* Bittn. (from Nio sumdo-Niri Sumdo-in Karnag, and probably also from the Pangpo Pass, both in the Zanskar basin), *Megalodon cultridens* Bittn. (from near Lingti Sumdo), and *M. Ladakhensis* Bittn. (from Shargol, at the northwestern end of the Zanskar basin; formerly described as *M. cf. gryphoides*). The first and last are Spiti forms. Two additional types, which are probably from Noric beds of this belt, are *Dicerocardium himalayanse* Stol. (from between Lahaul and Karag), and *Monotis salinaria* Schloth. (from Khar in the Zanskar basin); the former of these is a Spiti form, while the latter is the leading fossil of the Alpine Halstatt Limestone.[4]

Changchenmo valley.—In northeastern Ladakh, a narrow belt of "Jura-Trias" has been mapped by Lydekker in the Changchenmo, a tributary valley of the Shyok, north of Lake Pagong (Tso mo Gmalari) and to the east of Leh, and perhaps continuous with an outcrop of the same rocks observed some miles to the northwest on the Shyok river south of the Karakoram Pass. Eastwards, the Changchenmo outcrop probably unites with a broader belt from which, further west, it is separated by a wedge of older rocks ; this broader outcrop is crossed by the Chongling river. The sequence, mostly Kioto limestone, is accompanied by shaly beds apparently belonging to the Kuling series, and includes the characteristic white dolomites with numerous specimens of *Dicerocardium himalayense* and *Megalodon* (*Neomegalodon*) *triqueter*.[1]

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[1]. R. Lydekker. *Mem.* XXII, Map (1883).

[2]. *Mem. Connect. Acad.* VIII, Art. II, 47 (1935).

[3]. H. H. Hayden. *Mem.* XXXVI, 92 (1904).

[4]. Stoliezka also records "*Ammonites*" (*Proarcestes*) *ausseanus* Hauer

Lingzi Tkang.—North of the Chongling Pass, Triassic and Jurassic rocks occupy the lofty plains of Lingzi Thang, stretching far to the east and west and possibly into the Lokzung range to the north of the plains.[2]

Depsang plains, Karakoram Pass.—Another patch of Kioto limestone covers the Depsang plains on the south side of the Karakoram Pass. Of this we should have known more but for the premature death of Dr. Stoliczka on the Pass in 1874. From these beds come the curious spherical hydrocorallines, *Heterastridium* or *Syringosphæria*, known as "Karakoram stone" and similar to those found widely distributed in the Halstatt limestone of the Alps, in the Balkan Trias and in the island of Timor. Four species have been named by Duncan; *Heterastridium* (*Syringasphæria*) *medlicotti*, *H. intermidium*, *H. planum*, and *H. monticularium*, var. *aspersum*, another hydrocoralline from these beds is *Heterastridium* (*Stoliczkaia*) *porosa*.[3] From one of the moraines of the Siachen glacier in the Karakoram, Parona has identified ; *Dicerocardium mediofasciatum* Frech, *D. dolomiticum* Frech, *Megalodon bockhi* Par., *M. hœrnesi* Frech, and a doubtful *Omphaloptychia*. The small outliers of "Jura and Trias" recorded by Lydekker to the south of Nanga Parbat[4] are omitted from Wadia's maps.[5]

This outcrop belongs to the zone of fossiliferous Tethys sediments which, according to Auden, extends along the north of Karakoram watershed from the Pamirs for a distance of about two hundred miles, not as a continuous outcrop but apparently in a series of basins arranged *en échelon* and separated from each other by the underlying unfossiliferous Lower Palaeozoic rocks.[6]

Baltistan.—A curved belt of "Trias and Jura," lying synclinally in older rocks, occurs in Baltistan, extending from the Shigar river eastwards and northwards across the Biafo river and then northwestwards obliquely across the Biafo glacier into Hunza Nagar. In some places, the rocks are more or less metamorphosed, in others they are little changed and include thick limestones and dolomites together with black shales ; the dolomites and limestones with their characteristic red stains are described as very like the Changchenmo rocks. The Kuling Shales apparently accompany the Trias of this region[7].

Tosh Maidan-Gulmarg-Golabgarh Belt.—A ribbon-like belt of what has been referred to as the Upper Trias, which may well be the Kioto limestone, has been mapped by Middlemiss along the northeastern slopes of Pir Panjal, extending from Tosh Maidan, where it is cut off by a fault, southeastwards through Gulmarg to the Golabgarh Pass. From the Panjal Trap on both sides it is separated by a thin layer of Gondwana or Permian beds, except where the boundary is hidden by Pleistocene Karewa deposits. The slopes of the Pir Panjal above the outcrop are strewn with boulders of fossiliferous Triassic limestone, proving that the exposure was more extensive than it is now.[1] The Lower and Middle Trias are absent, hidden by moraine and alluvium, or represented by a sequence either without fossils or with a fauna too scanty for stratigraphical purposes. The lowest horizon is of pale, thin-bedded shale with *Pecten* and *Pseudomonotis*. The bulk of the exposure of limestone which is practically unfossiliferous strongly resembles the enormously thick limestone of similar age on the opposite side of the Kashmir valley already described ; in some of the beds corals and crinoids are imperfectly shown. In places the limestone has a very thin-bedded, platy structure like that of slate[2].

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[1] F. Stoliczka. *Mem.* XXII, 182 (1883).
[2] R. Lydekker. *Mem.* XXII, 182-183 (1883).
[3] *Rec.* XXIII, 80(1890) ; *Q. J. G. S.*, XXXVIII, 69 (1882) ; P. Oppenheim, *Central f. min.*, etc., 722 (1907).
[4] R. Lydekker. *Mem.* XXII. Map (1883).
[5] *Rec.* LXVI, Pt. 7(1932) ; *Ibid.*, LXVIII, Pl. 12(1934).
[6] P. Kennit Mason. *Himalayan Journ.*, X, 43 (1938).
[7] Lydekker. *Mem.* XXII, 188 (1883).

Outliers on the southwestern flank of the Pir Panjal.—Two small outcrops of Upper Trias have been mapped by Wadia on the southwestern flank of the Pir Panjal, twelve miles away from the Tosh Maidan belt, and there may be trifling occurrences of the same rocks elsewhere along this line of strike. Each of the two outcrops is about 50 feet thick, and is composed of grey semi-crystalline limestone overlain by grey crinoidal limestone with occasional lamellibranchs. In the larger of these two exposures—that at Mandi—the Trias is underlain by a small thickness of Permian beds with *Pesudomonotis*, which rest unconformably upon the Panjal Trap, the later inlying the Nummulitic limestone ; at Trekanna the Trias rests directly upon the Panjal Trap. In a line with the above is a narrow outcrop of Permian beds at Sangliani, which may or may not be accompanied by an insignificant amount of Trias[3].

Himalaya-Hazara syntaxis.—An extremely narrow belt of Trias and Infra-Trias, fragmentarily developed in discontinuous, faulted strips, has been mapped by Wadia in a northwestwardly continuation of the above small outliers. In this direction it has been drawn circling round the Mozaffarabad syntaxis into Hazara. It is accompanied by an outcrop of Panjal Trap of not much greater width, except to the west of the curve where the trap is absent and the Trias with Eocene and other rocks, is sandwiched in between vertical Miocene beds (Murrees) on the one side and Dogra Slates on the other. In the majority of sections, the Trias occupies a position between the Panjal traps and the Nummulitic limestone in the recumbent folding of this area. It is a little more thickly developed in the hills southeast of Uri, and in the Kunhar gorge east of Paras. In the latter section, the rocks which are described as resembling the Hazara rather than the Kashmir Trias, consist of dark grey or rusty brown, thick-bedded, sandy limestone with ochreous blotches, with black shaly partings and strings of comminuted bivalves, corals and crinoids, but no ammonoids ; *Dicerocardium* and a doubtful *Megalodon* are recorded.[4] No trace of the Zewan beds has been observed in the hills northwest of Uri.

HAZARA AND ATTOCK.

Hazara district.—The Kioto Limestone, most of it probably Upper Trias occurs in the hills of Hazara both in the "Slate zone" and the "Nummulitic zone". In the Slate zone it is accompanied in the great majority of cases by the

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[1] D. N. Wadia. *Mem.* LI, 249 (1928).

[2] C. S. Middlemiss. *Rec.* XLI, 129 (1911).

[3] *Mem.* LI, 250 (1928).

[4] *Rec.* LXV, 212 (1931).

Spiti Shales and Giumal Sandstone (Upper Jurassic to Upper Cretaceous), very frequently also by a substantial thickness of Eocene rocks, the associated strata forming long thin lenticular strips or ribbon-like bands—faulted synclinal outliers in the Attock Slate. This persistent mutual accompaniment is an almost invariable feature of the cliff sections in these hills. Along the northern part of the Slate zone the Kioto Limestone usually overlies one or other member of the Infra-Trias, but in the more southerly parts it is separated from the slate, into which it is tightly folded, only by a thin quartzite and sometimes not even by that. In some places there is evidence of more than one fold in an outcrop. Among the dark barren slopes of the slate, these outliers are seen as occasional craggy crests. In the Nummulitic zone—a zone of long steady strike ridges—the Spiti Shales are not found, but the Trias-Jurassic-Cretaceous sequence is seen in similarly shaped and similarly disturbed anticlines. In both the Slate and Nummulitic zones the boundary of the Mesozoic outcrops, especially the south-eastern boundary, is often a fault. According to Middlemiss, the thickness of Kioto Limestone in Hazara varies from 500 feet to a maximum of 1200 feet near Sirbunnuh seven miles to the east of Abbottabad but below it is a basal stage of 50 to 100 feet of volcanic material, haematite breccia, quartzites, shales, etc., which should be included in the Trias.

Of this basal stage the bottom beds consist of grey and white chert. The volcanic material is well seen on the north face of Sirban hill, in the form of very hard, pink, white or greenish bands, weathering with a rough surface, and probably composed of a much altered rhyolite. In the microfelsitic groundmass obscure traces of flow-structure can be made out but no phenocrysts of othoclase or quartz and no spherulitic or perlitic structures. The brecciation frequently seen in these rocks is perhaps a contemporaneous phenomenon. In Sirban hill these supposed lavas are followed by some buff or purplish micaceous shales, and these by an earthy or pisolitic haematite.[1]

The limestone, above this basal stage, is very massive and thick-bedded, and rarely forms dip slopes. It is not so evenly bedded as the Infra-Trias and weathers into much darker colours. The fresh rock is generally dark grey, mottled with elongated oval vermiform ochreous blotches. Sometimes it approaches a deep purple with a few deep yellow courses; occasionally it is of a pale blue-grey tint like that of the Nummulitic limestone. In one place, a few spheroidal ferruginous concretions have been recorded in the limestone, and a minute oolitic structure is characteristic of much of it. The rock is slightly arenaceous but has no dolomitic tendency. Lines of comminuted shells and in places better preserved outlines of molluscs on limestone surfaces are observable, and the following forms have been made out: *Megalodon* sp., *Dicerocardium* sp., *Chemnitzia* sp., *Gervillia* sp., *Rhynchonella* sp., *Terebratula* sp., and *Alectryonia haidingeriana* Emm.[2] Chiefly on account of the presence of the first two genera, the beds have been assigned to the lower part of the Upper Trias. At the base of the limestone, above the bottom quartzite southeast of Bugnotur (Bagnotur), some grey shales have yielded a few fossils, but all of them too imperfect for precise identification; Das Gupta's determinations of these are: *Megalodon* cf. *pumilus* Gümb., *Pecten* cf. *standerbergeri*

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[1] C. S. Middlemiss *Mem.* XXVI, 26 (1896).

[2] *Alectryonia haidingeriana* is an Alpine species; a comparable form is found in the Napeng Rhaetic) bed of Burma.

Klipst., a small ammonite and a lamellibranch resembling *Vola* sp.[1] The Lower and Middle Trias have not been observed either in Hazara or in the Attock district.

Attock District.—In Attock, the volcanic zone appears to be unrepresented and the only possible equivalents of the basal stage of Hazara are some ferruginous shales, bleached shales and marls, which have been observed in the Kioto Limestone but whose precise horizon is unknown ; three hundred feet of these marls and ferruginous shales are exposed in the railway cutting through the Kala Chitta hills, north of the most northerly tunnel, and red beds of a similar nature are recorded in the hills east of Campbellpur and in the Kheramar hills[2]. It is possible, however, that these ferruginous beds are younger than basal Trias and correspond to the *Sulcacutus* beds which in the central Himalaya occur at the top of the Kioto Limestone.

In the Kala Chitta hills, the main outcrop of the limestone, with a few subordinate bands, stretches irregularly from a point northwest of Chharat to the Indus and beyond it. Other exposures lie immediately east and southeast of Campbellpur cropping out with the Eocene from the alluvium ; a few additional patches of it are seen between Campbellpur and Hassan Abdal, and beyond the latter eastwards. The base of the limestone is not exposed ; in the western parts of the Kala Chitta 1,600 feet have been measured but not more than half this thickness is recorded in the easterly portion of the range. The formation, exposed in the cores of steeply-inclined or recumbent E.-W. anticlines, is of the same character as the Hazara rock, and is succeeded by beds which from their fossil content correspond to both the Spiti Shales and the Giumal Sandstone.

The Kioto Limestone of the Kala Chitta and the Campbellpur area is described as drab-grey, irregularly mottled with buff, lavender or pink, well-bedded but less frequently bedded and finer in texture than the Nummulitic limestone ; sometimes there is an alternation of buff and grey bands. The mottling probably marks the remains of fossils. The fracture of the rock is smooth and generally curved, and the weathered surface is pitted or grooved like that of the nummulitic limestone ; the rock seldom forms dip slopes. Bands of comminuted shells are not infrequent and the presence of an Upper Triassic horizon is proved by the occurrence of a species of *Indopecten* found in a light yellow shaly matrix near Garhiala. From the railway tunnel mentioned above, Dr. Muir-Wood has identified *Rhynchonella* cf. *bambanagensis* Bittn. and a doubtful *Halorella*, from beds of probably Noric age[3].

CHITRAL AND THE PAMIRS.

From its description, the Pamir Limestone of Hayden, the most persistent and conspicuous stratigraphical element in the Russian Pamir, would appear to be a northward extension of the Kioto, which in part it resembles. It extends southwards through the Afghan Province of Wakhan, over the Shawitakh Pass into the extreme north of Chitral, and a branch of the outcrop crosses the Ak Su below Aktash. It is often underlain by dark shales and in places by a limestone resembling the Fusulina Limestone except that it is unfossiliferous. It is a very thick formation, thin-bedded in beds from six inches to one foot thick, sometimes pale grey, sometimes darker, usually hard and compact but occasionally shaly.[1] In the Aktash area it is steeply folded. Sections of *Megalodon* are sometimes to be seen in the rock, and from the summit of Lakhshakh Pass, in a bed of shaly limestone made up almost entirely of comminuted brachiopods, Hayden collected crushed specimens of the Triassic genus *Halorella*. From the lower portion of the formation, in the same part of the eastern Pamir, Stoliczka collected from limestones intercalated in black crumbling shales: *Halorella rectifrons* Bittn., *H. stoliczkai* Suess, *H. pedata* Bronn., *Monotis salinaria* Schloth. and *Thamnastræa rectilamellosa* Winkl. *Monotis salinaria* is a Spiti form; the genus *Halorella* has not been found in the Himalaya[2], but occurs in the Upper Trias of Malaysia.[3] That the Pamir limestone, like the Kioto, trespasses into the Jurassic, is proved by impressions of Jurassic ammonites such as *Perisphinctes*.

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[1] *J. A. S. B.*, New Ser., XI, 253-254 (1916).

[2] G. de P. Cotter. *Mem.*, LV, 80 (1933).

[3] *Pal. Ind.* New Ser., Vol. XX, Mem. 6, 3-5 (1937).

Triassic rocks have been recognised by Stoliczka in the limestone cliffs of the Koktan range of Chinese Turkistan, to the north of Kashgar, between that town and Lake Chaderkul which is close to the Russian frontier; the Kotkan is one of the southern branches of the Tian Shan.[4] The basal portion of what is believed to be the Triassic system here consists of undulating, greenish or purplish shales overlain by dark, nearly black, limestones in thick or thin bands, the latter being earthy. In one of the limestones are: an abundance of *Megalodon triqueter*, a large *Pinna*, a *Spiriferina* comparable to *S. stracheyi*, the coral *Lithodendron*, and numerous small gastropods. Other thinner limestones are crowded with the remains of crinoid stems and a branching ceriopore.

A similar dark limestone, but in this case unfossiliferous, is present in the Terek-tagh, another range farther north, and is accompanied by slaty rocks and the characteristic white dolomitic limestones of the upper Trias.

AFGHANISTAN AND ADJACENT PARTS OF THE NORTH-WEST FRONTIER.

Doab Series.—The volcanic Doab series, which is exposed to the WNW of Kabul and may range into the Trias, has already been considered. In the Chehil section in Afghan-Turkistan, the Saighan rocks, which here crop out as an elongated E.-W. inlier in the Cretaceous, overlie a calcareous sandstone which has yielded specimens of *Halobia* or *Daonella* of Upper Triassic or perhaps younger affinities.[5] Hayden suggests that this sandstone is a local variation of the upper part of the Doab volcanic series.[6]

Khingil Series.—East of Kabul, on the northwestern side of the high Khingil range which separates the Kabul plain from Jagdallak, Hayden found limestones and interbedded shale with badly preserved ammonoids and lamellibranchs including "*Meekoceras*" sp., *Ophiceras* sp., and *Pseudomonotis* sp. The succession of beds forms a single stratigraphical unit to which the name of the Khingil series has been given (see page 846). Its strata probably range from Carboniferous to at least the Upper Trias and possibly beyond, and include beds which lithologically and faunistically characterise the Lower Trias of the Himalaya ; below them are limestones with *Spirifer* and *Productus*. The Triassic limestones are locally altered by intrusions of granite and serpentine.

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[1] *Rec.* XLV, 136, 292 (1915).

[2] Diener. *Mem.* XXXVI, 117 (1912).

[3] *Denkschrift. Kais. Akad. d. Wissench.*, LXI, 432-466 (1894).

[4] *Rec.* VII, 82 (1874).

[5] At first identified as *Daonella lomelli*, and an associated lamellibranch as *Monotis salinarian*. According to Mr. Tipper, neither of these identifications is correct. *Rec.*, XLII, 72 (1912); H. H. Hayden. *Mem.* XXXIX, 32 (1911); A. C. Seward. *Pal. Ind.*, New Ser., Vol. IV, Mem. p. 2 (1912).

[6] *Mem.*, XXXIX, 77 (1911).

The Khingil series probably occupies most of the hills between the eastern edge of the Kabul plain and the Panjshir river, and extends northward across the Kabul river towards Kohistan ; to the south it may form the Karkacha range in Tezin, and may be continuous with a belt of the same rocks cropping out in the ranges which skirt the Safed Koh along its southern slope. An inlier among the Tertiary beds west of Sarobi has yielded *Megalodon* sp. and *Dicerocardium* sp., proving that the Upper as well as the Lower Trias forms part of the series.

To the south of the Safed Koh crest, the Khingil series is exposed in the Chura and Bazar valleys, and is cut off from older rocks of Palaeozoic age to the north by a long line of E.-W. faulting. Traced eastwards, the outcrop curves northeast and ends in the hills overlooking the Peshawar plain. The rocks along this exposure are highly folded, the folds being frequently reversed and faulted.[1] The Triassic portion of the sequence, which is well seen south of Bagh, lies immediately under the Rhaetic limestone and is of great thickness ; it is composed of red gritty shales, passing down into finer beds, overlying grits and conglomerates which in their turn succeed reddish-brown needle shales. Occasional thin bands of limestone occur. The most extensive member of the Trias of this locality is the needle shale which may be several hundred feet thick and has yielded plant impressions It is sometimes interstratified with thin bands of coarse sandstone. According to Griesbach, the shales are in places alum-bearing. The conglomerates consist of large rounded blocks and pebbles of limestone, sandstone and occasionally gneiss, lying in a coarse, sandy matrix. On the south side of the Bazar valley, west of Peshawar, the red, gritty shales of the Trias are seen dipping under limestones of Permian age.

BALUCHISTAN.

A wide outcrop of Triassic beds was proved by Mr. E. Vredenburg to be present to the east of Pishin in the highlands south of the upper Zhob valley.[2] The structure of the area is complicated and the inclusion within the outcrop of several narrow, compressed synclines of Tertiary rocks confirms the suspicion that the succession is repeated many times by folding. No estimate of the thickness has been found possible.

The rocks consist largely of slaty shales, usually greenish in colour but sometimes slate-coloured or reddish, with harder intercalations. Lithologically, they are very similar to the Tertiary Kojak Shales on the north side of the same valley, but the intercalations in the case of the Trias are of black compact limestone and not calcareous sandstones as they are in the younger system. Pressure has induced slaty cleavage, and fossils are scarce. The most frequent fossil is *Monotis salinaria* Schloth., which occurs in a fragmentary condition at numerous places all over the outcrop. Of the ill-preserved cephalopod casts, the only one identified *in situ* is *Halorites* aff. *subcatenatus* Mojs. from the eastern part of the exposure near Mach ; from boulders in the river beds have been obtained *Didymites afghanicus* Mojs., *Dittmarites* ănd *Distichites* sp. (?), *Celtites* sp. (group of *acuti-*

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[1] H. H. Hayden. *Mem.* XXVIII, 97 (1898).

[2] *Rec.* XXXI, 162 (1904).

plicatus) *Paratibetites* aff. *törnquisiti* Mojs. and *Diphyllites* (*Rhacophyllites*) *vredenburgi* Dien. The horizon indicated is that of the Noric, especially the middle division thereof.[1]

There is reason to believe that this series is brought up again by faulting to the west of Quetta, where, in the Brewery Hill, have been obtained a few fossils of Triassic appearance. These include several specimens of a phylloceratid recalling *Diphyllites vredenburgi*, some small globose forms greatly resembling *Ptychites* and another fragment which seems to belong to the genus *Cladiscites*.[2]

In the Fort Sandeman area of north Baluchistan, Dr. A. L. Coulson collected a specimen of *Didymites*, a genus characteristic of the Lower Noric ; the rocks from which it was obtained form part of a sequence similar to the shale, limestones and sandstones exposed in the gorge of the Kapip Khwara.[3]

Some two hundred and fifty miles south of Quetta, a boring in Khairpur State supplied a considerable number of fragmentary fossils ; from the lower levels were obtained an ammonite referable to the Arcestidae and a possible orthoceratoid cephalopod, suggesting the presence of Triassic rocks.[4]

BURMA.

Arakan Yoma.—Until very recently it was generally supposed that the Axial group of Theobald, admittedly a heterogeneous formation of unknown stratigraphical limits, included beds which had yielded Triassic fossils including a species of *Halobia* or *Daonella*. The question is discussed fully by Dr. E. L. G. Clegg, who advances grounds for suspecting that the fossils in question, Triassic though they undoubtedly are, did not come from the Arakan Yoma, where the Axial beds are exposed but from Karenni.[5] The "Axial group" is described in the chapter dealing with Cretaceous.

Northern Shan States.—Over the greater part of the Northern Shan States Triassic deposits have not been recognised. In North Hsenwi, however, between the top of the Plateau Limestone and strata thought to be Rhaetic, Mr. G. V. Hobson found a series of dark grey, thin-bedded limestones with interbedded sandstones, passing up into carbonaceous sandstones ; the beds are unfossiliferous but might represent some stage of the Trias—perhaps the Noric, which is so substantially developed to the east in Yunnan.[6] At Na-hkam in the same State, west of the town of Hsenwi and north of Lashio, Dr. M. R. Sahni has found interstratified among dolomites similar to those which form the bulk of the Plateau Limestone, a series of thin-bedded, argillaceous limestones and shales, which have yielded a very interesting fauna apparently ranging from the *Otoceras* zone, although this genus itself has not been found, to the Owenitan ; in addition to ammonoids, gastropods are present in large numbers. The following is a list of the forms provisionally identified ; *Xenaspis carbonaria* Waag., (found in the Permian of the Salt Range and the Chitichun erratics); *Ophiceras* (*Glyptophiceras ; Lytophiceras*) sp. ; *Vishnuites* sp. ; *Paravishnuites* sp. ; *Hemiprionites* (*Goniodiscus*) sp. ; *Aspenites* (an American genus, found also in Timor) ;

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[1] C. Diener. *Rec.* XXXIV, 20 (1906).

[2] G.H. Tipper. *Rec.* XXXVI, 133 (1907).

[3] Shown as Cretaceous on the 32-mile geological map.

[4] *Gen. Rep. Rec.* LX, 19 (1927).

[5] *Mem.* LXXII, 178-195 (1928).

[6] *Rec* LXIII, 92 (1930).

Owenites sp.; *Kashmirites* sp.; a species of *Juvenites* (*Nannites*) allied to *J. hindostanus* (Dien.) and *J. herbarti* (Dien.), both of them found in the Otoceras Beds of Spiti; another species of the same genus having resemblances to "*Nannites*" *bittneri* Mojs. "*N*" *fugax* Mojs. and "*N*" *spurius* Münst. of the Mediterranean Trias and a frequent form belonging probably to a new genus of the Hungeritidae. *Pleurotomaria* and *Naticopsis* are the dominant genera among the gastropods the former being the most prolific both in numbers and species; one of the latter is said to be comparable to *Naticopsis khurensis* Waag. from the Salt Range and central Himalaya. A single species of *Holopella*, very similar to *H. trimorpha* Waag. of the Salt Range Upper Productus Limestone, is recorded, and the genus *Neritomopsis* is represented by more than one species. A single specimen belongs to the genus *Platystoma* (? *Platyceras*), and several ill-preserved fossils have been referred to *Murchisonia*. *Trochus* is represented, and a number of specimens are probably assignable to the Neritopsidae.[1] Among the lamellibranchs, forms belonging to *Schizodus* are the most common, but *Pseudomonotis*, *Aviculopecten*, and a doubtful *Lucina* are reported. The only brachiopod is a species of *Lingula*.

These beds are no longer thought to form an integral part of the Dolomitic type of the Plateau Limestone, but are probably faulted thereinto. To this presumed dislocation they probably owe their preservation, but their relationship to the Plateau Limestone is obscured by thick surface debris. Sahni remarks that their discovery is due to the fortunate accident of a stream happening to traverse their outcrop; failure to find the beds elsewhere, therefore may be due to concealment beneath alluvial deposits.

This is the only Lower Traissic fauna known between the Himalayan region and Indo-China. In the complete absence of brachiopods, with the exception of the chitinous *Lingula*, the fauna shows a marked contrast to its equivalent in the Himalaya; at the same time, the species of *Ophiceras*, *Juvenites*, *Kashmirites* and *Hemiprionites* are allied to those of the Himalaya and the Salt Range and, as Dr. Sahni remarks, were a deeper phase of this assemblage discovered in the Shan States, it would in all probability show a still greater affinity with the Himalayan and Salt Range faunas. In the absence of calcareous brachiopods and in other respects, the Na-hkam fauna displays a close resemblance to one in east Greenland, the species of *Vishnuites* and *Ophiceras* found in the two regions being closely allied. Dr. Sahni suggests that this entire absence of the calcareous brachiopods, which are such a determining feature of the Burmese Permian (Plateau Limestone), illustrates what may be an important break at the top of the Permian.

Karenni.—Specimens said to come from Karenni include some very well preserved examples of an *Halobia* or *Daonella*, and a species of *Monotis*.[2] Other specimens occurring in a hard black limestone very similar to that containing the Karenni specimens, were reported to have been derived from the Axial Beds of the Arakan Yoma, but it appears probable that they were wrongly labelled and came in reality also from Karenni; they comprise an *Halobia* or *Daonella* distinct from any described Indian species but allied to the one mentioned above, and numerous lamellibranch casts and fragments including some *Monotis*-like shells and an *Avicula* very close to *A.* (?) *girthiana* Bittn., a Himalayan type.[3]

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[1] *Rec.* LXVI, 27, 97-98 (1932).

[2] G. H. Tipper, *Rec.* XXXIV, 134 (1906).

[3] A. Bittner, *Pal. Ind.* Ser. XV, Vol. III, pt. 2, 48 (1899).

BURMO-SIAMESE FRONTIER.

In the Amherst district of Lower Burma, the hills between the Dawna range and the Siamese or Thailand frontier, which is here formed by the Thaungyin river, are composed mainly of a limestone overlain unconformably by a series of red sandstones resembling the Kalaw Red Beds of the Southern Shan States. The limestone forms the cores of the chief ranges, the main exposure occurring between the Thaungyin and its tributary the Mepale river, stretching from Htichara northwards, and probably continuous with the outcrop in the Thaungyin gorge above Kamawkala village, in the extreme north of the district. It has been called by Dr. Cotter the Kamawkala Limestone after the well-known peak of that name southwest of the village. Several minor inliers occur along the Thaungyin river and in the hills north-east of Htichara; the most southerly of them lies on the right bank of the river, a few miles south of the Phalu, and due east of Moulmein. The rugged and castellated profiles characteristic of the limestone can be recognised in the distant Siamese ranges and bear witness to a wide eastward extension of the rock.

The main exposure, north of Htichara, is flanked on the east and south by the Red Sandstone of Kalaw Beds, probably of Lower Jurassic age, and along its southwestern boundary by Tertiary beds. Both the limestone and the red sandstones are highly disturbed and often vertical in dip, the former being frequently contorted and crushed.

The Kamawkala Limestone is a hard, grey, crystalline rock, often characterised by a network of calcite veins ; near Htichara the rock is dolomitised and forms bolder and more massive hills. A few badly-preserved fossils have been obtained, the best of which are brachiopods and molluscs and indicate Upper Triassic age. The following forms have been identified by Professor J. W. Gregory, Dr. J. Weir, Dr. F. Trauth and Dr. J. Pia.[2]

ALGA—

Holosporella siamensis Pia (the sporangical tube of dasycladacean showing resemblances to *Diplopora phanerospora* Pia. and to *Aciculella bacillum* Pia, the former probably from Triassic beds, the latter undoubtedly Ladinian),
Physoporella ? sp.,
Sphaerocodium sp.,
Diplopora sp.,
A fragment resembling *Dovcenipora.*

ACTINOZOA—

Stylina sp.,
Stylophyllopsis thaungyinensis Greg.,
Centrastraea cotteri Greg.,
Meandraraea orientale Greg.,
Thecosmilia sp.,

BRACHIOPODA—

Rhynchonella bambanagensis Bittn. (a Himalayan form Noric age),
,, cf. *concordiae* Bittn., (an Alpian species Noric age),
,, *fissicostata* Suess. (close to *R. salteriana* a form found in some unknown horizon of the Middle Trias of the Himalaya).

LAMELLIBRANCHIATA—

Cheamys sp. (with affinites to *C. valoniensis* Newt., a form ranging widely and found in the Malaya Peninsula).
Ostrea sp.

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[1] G. De Cotter. *Rec.*, LV, 275 (1923).
[2] *Rec.*, LXIII, 155-181 (1930).

Of the indeterminable ammonoid fragments the best preserved has been compared by Dr. Spath to the Rhaetic *Choristoceras ammonitiforme* Gumb. while another is a compressed haloritid resembling the Noric *Jovites*; an incomplete fragment showing only half a whorl, according to Dr. Trauth, has a ribbing nearest to a *Juvavites* allied to *J. buticum* Dien., and another specimen is regarded by Professor Von Arthaber as belonging to the genus *Trachyceras.* In addition there are remains of sponges, crinoid stems and echinoid spines, and sections of a large indeterminable gastropod.

Whether the Kamawkala should be regarded as an upward extension of the Plateau Limestone, as has been suggested,[1] is a question of convention best postponed till more is known of the upward range of the Plateau rock in other parts; for the present it is best considered apart. Fossiliferous Triassic rocks are present in the Malay Archipeago, and the Middle and Upper divisions have been recognised in the Malay Peninsula, where the rocks consist of shale, quartzite and coarse conglomerate.[2]

YUNNAN.

Introduction.—The sea appears to have invaded certain portions of the Chinese province of Yunnan at various times during the Triassic period, and the system is represented to-day by limited relics which, in the eastern parts at least, owe their preservation apparently to faults that have let them down.[3] Space will not permit of a detailed description of the Trias in this southwestern province of China, and the various provinces of French Indo-China to the south, but a brief consideration of Dr. Coggin Brown's important traverses in the former region and of Dr. Cowper Reed's equally valuable palaeontological contributions is advisable, since their results are likely to throw light upon further work in the Shan States and other parts of Burma.

In Yunnan, the Trias is in general steeply folded, and represented by all three divisions which are said to be separable from each other by distinguishing fauna. The Lower division has not been definitely recognised in the more westerly parts but in the east it has a littoral facies with a typical Werfen fauna and passes up into the Middle Trias;[6] between the Mekong and the Yang-pi Ho it seems to be represented by at least a part of a great arenaceous, argillaceous and carbonaceous formation of sub-aerial and in part lagoonal origin, known as the Red Bed series.

The Red Beds, which, from a lithological standpoint, are reminiscent of portions of the Gondwana sequence, lie unconformably upon the Upper or Lower Permian. They are followed by, or, as far as their uppermost horizons are concerned, pass laterally into, deposits containing a flora which has been assigned to the Rhaetic: *Taeniopteris lecleri* Zeill., *Clathropteris platypylla* Goeopp., *Podozamites distans* Persl.,[7] in many cases, however, its contacts with other formations are faults.

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[1] G. de P. Cotter. *Rec.* LV, 282 (1923).

[2] J. B. Serivemor. "Geology of the Malay State", 62 (1931).

[3] J. Coggin Brown. *Rec.* XLIV, 97 (1914).

[4] J. Deprat. *Mem. Serv. geol. Indo-Chin.* Vol. I, Fasc. 1, 176-185 (1912).

[5] M. Ed. Sawrin and M. Ch. Jacob. *C. R. Acad. Sci. Paris*, CXCVII, 174 (1933); J. Coggin Brown. *Rec.* XLVII, 229 (1916).

[6] M. Valct. *Bull. Soc. Geol. France.* Vol. III, Ser. 5, p. 46 (1933).

[7] *Mem.* XLVII, 56-57 (1920).

According to Dr. Coggin Brown, the predominant types are reddish sandstones, often in thick bands, and purple and greenish shales, producing a monotonous kind of scenery pervaded by a light red clay soil. Near the T'sang Shan granite intrusion, the shales have been metamorphosed to purple slates. The base is often characterised by a thick conglomerate with pebbles of red jasper, red and green porphyry and other rocks. The Red Beds are of great economic importance by reason of the extensive deposits of rock-salt which occur in them at many places.[1]

Belt between Puerh Fu and the Mekong.—In southeastern Yunnan, west of Puerh Fu and between that town and the Mekong, a belt of marine Trias and Rhaetic, from twenty-five to thirty miles wide, is in contact both on the west and on the east side with the Red Beds.[2] This belt consists mainly of calcareous shales disintegrating to soft, yellow marls, and grey-blue limestones, often with crinoidea and frequently chracterised by calcite-bearing cracks; a yellow dolomitic limestone is found in places. From two or three localities the following Middle Trias fossils have been collected :—

SPONGIDA—
  Steinmannia cf. *utriculus* Vin. de R.,

ACTINOZOA—
  Thecosmilia cf. *clathrata* Emm.,
  Spongiomorpha sp.

CRINOIDEA—
  Encrinus cf. *liliiformis* Miller.

BRACHIOPODA—
  Spiriferina (?) sp.

LAMELLIBRANCHIATA—
  Entolium cf. *subdemissus* Münst.,
  Pecten aff. *subalternans* d'Orb.,
  Posidonomya cf. *wengensis* Wissm.,
  Gonodon sp.,
  Anodontophora cf. *griesbachi* Bittn.,
  Palaeoneilo cf. *subtenella* Krumb.,
  Daonella indica Bittn.

GASTROPODA—
  Amauropsis cf. *paludinaris* Münst.

CEPHALOPODA—
  ? *Trachyceras* sp.,
  ? *Pterotoceras* sp.

From another part of the same belt (between Man-mu and Na-ku) the following Upper Triassic lamellibranchs have been identified :[3]

Pecten (*Syncyclonema*) *quotidianus* Healey,
Lima (*Palgiostoma*) aff. *nuda* Parona,
Pergamidia nakuensis Reed,
Mysidioptera sp.,
Gervillia cf. *shaniorum* Healey,
  ,, *Sancti-galli* Stopp.,
  ,, cf. *praecursor* Quenst..
  ,, aff. *paronai* Broili,
Modiola frugi Healey,
  ,, cf. *raibliana* Bittn.,

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[1] *Mem.* XLVII, 56-57 (1920).
[2] *Rec.* LIV, Pl. 20, 315 (1922).
[3] F. R. Cowper Reed. *Pal. Ind. New Ser.*, Vol. X, Mem. 1, 289 (1927).

Anodontophora manmuensis Reed,
,, cf. *ovalis* Parona,
Cypricardia (?) cf. *garandi* Mansuy.

From yet another locality, beyond Huang-to-chai, in the same area, come the following which are also probably Upper Triassic :—

Lamellibranchiata—
Cassianella beyrichi Bittn.,
,, cf. *verbeeki* Krumb.,
Gervillia protracta Reed,
Pinna aff. *lima* Boeham,
Gonodon cf. *mellingi* Hauer,
Cardita sp.,
Cardium aff. *martini* Boettg.

Gastropoda—
Coelostylina sp.,
Acmaea delicata Reed.

Cephalopoda—
Sirenites aff. *senticosus* v. Dittm.,
Anatomites sp.

Belt between Ta-lu and Hsin-chuang.—In north Yunnan another N.-S. belt of Trias and Rhaetic, over 40 miles in width, is exposed to the east of Li-kiang Fu, between Ta-lu and Hsin-chuang, and is traversed further south by the Yang-tze-Kiang. On the west it is in contact with the Red Beds, perhaps along a fault; on the east it is succeeded by a thick succession of diorites and associated rocks. The Triasso-Rhaetic succession consists of bands of limestones and shales, the latter sometimes yellow or white but mostly red or purple and in places with carbonaceous partings. Bands of sandstone are frequent and along one section form the dominant rock. One of the most interesting features of this belt is the occurrence of coal seams of good quality which are mined; from a six-foot seam the Rhaetic plants mentioned above were collected.

Exposures east and Southeast of Erh-hal.—Perhaps continuous with the previous exposure are the patches of Trias (? and Rhaetic) found to the east and south-east of Erh Hal, a lake 70-100 miles south of Li-kiang Fu and carrying on its western shore the town of Ta-li Fu. These form part of the Mesozoic basin of Yunnan-i, in probably faulted contact on the west with the Lower Permian and contiguous on the east, perhaps also along a fault, with the Red Beds. The rocks comprise the same types as those found to the northeast in the Yang-tze-Kiang valley and include coal seams and carbonaceous shales in which plant remains occur. From Yunan Hsien in the Yunnan-i basin Sir Albert Seward has determined : *Podozamites distans* (Persl.) Braun., *P. lanceolatus* (L. & H.), *Dictyophyllum* sp. and *Ginkgoites* sp. ; while in a collection from Miao-tsway, Prof. B. Sahni has recognised *Equisetites sarrani* (Zeill.), *Dictyophyllum remauryi* Zeill., *D. nathorsti* Zeill., *Cycadites saladini* Zeill, and possibly *Pelourdea zeilleri* Sahni. The flora is much the same as that of the Hongay Beds of Tonkin, formerly regarded as Rhaetic but now placed by French observers in the Noric.[1] Some dark calcareous shales have yielded fish remains, but from Miao-tsway a comparatively copious marine lamellibranch fauna was obtained by Coggin Brown and identified by Cowper Reed as follows :—

Nucula strigilata Goldf.,
,, ,, var. *extensa* Reed,
,, *subaequilatera* Schäfh., var. *tswayensis* Reed,
,, cf. *subobliqua* d'Orb.,
,, cf. *misolensis* Jaw.,

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[1] *Rec.* LIV, 78 (1922).

Leda (*Nuculana*) *perlonga* Mansuy,
,, ,, *yunnanensis* Reed,
,, ,, *sulcellata* Münst.,
,, cf. *alpina* Winkler.,
Palæoneilo praeacuta Klipst.,
Cucullaea (*Macrodon*) cf. *impressa* Münst.,
Gervillia aff. *planata* Broili,
,, aff. *wagneri* Winkl.,
,, (*Hœrnesia*) cf. *inflata* Mansuy.
Avicula krumbecki Reed,

Cassianella cf decussata Münst.,
,, cf. *gryphœata* Münst.,
,, cf. *dussaulti* Patte.,
Halobia aff. *miessenbachensis* Kittl.,
Myophoriopsis cf. *latedorsata* Krumb.,
Pachycardia (?) cf. *lutrariaeformis* (Krumb.),
Myophoria subvestita Krumb.,
,, *verbeeki* Boettg., var. *curta* Reed,
,, cf. *volzi* Frech,
,, cf. *napengensis* Healey,

Myophoricardium cf. *lineatum* Wohrm.?

Pecten cf. *nerei* Münst.,
,, (*Syncyclonema*) *subsecutus* Reed,
Lima aff. *angulata* Münst.,
Mysidioptera cf. *incurvostriata* (Gümb.)
Cardita (*Palaeocardita*) *globiformis* Boettg., var. *healeyi* Reed,.
,, ,, *mansuyi* Reed,
,, ,, cf. *trapezoidalis* Krumb.?
Megalodon aff. *klipsteini* Bittn.,
Rhaetidia aff. *zitteli* Bittn.,
Dimyodon cf. *subrichthofeni* Krumb.

This is an Upper Triassic fauna, as is probably also the small assemblage (Carnic) collected from another locality in the same basin, including : *Halobia cassiana* Mojs., var. *yunannensis* Reed ; *H. charlyana* Mojs., var. *pluriradiata* Reed ; *Hoferia* sp., *Leda* (*Nuculana*) aff. *perlonga* Mansuy, and *Palaeoneilo suborbicularis* Reed.[1]

To some undetermined horizon of the Trias belong some laminated, light grey limestones, with platy, dark greyish-blue bands showing impressions of bivalves, found by Dr. Coggin Brown about two miles below Lameng near the ferry across the Salween ; among the fossils is a coral which Dr. Cowper Reed has determined as *Thecosmilia* aff. *weberi* Vin. de. Regny, a form found in the Trias of Timor.[2]

Thus the Trias is well represented in Yunnan, the Middle and Upper division by marine beds with a fauna which in the west consists essentially of lamellibranchs and is characterised by a rarity of corals and an almost complete and remarkable absence of cephalopods and brachiopods. A brachiopod facies quite different from the above has been found by Professor J. W. Gregory in the Upper Trias of Janula,[3] while the Trias of eastern Yunnan contains many cephalopods.

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[1] *Pal. Ind.* New Ser. Vol. X, Mem. 1, 244 (1927).

[2] *Rec.* LXX, I, 180 (1936).

[3] *Phil. Trans. Roy. Soc.* Vol. 213, B., p. 269 (1925).

CHAPTER XXII.

THE GONDWANA SYSTEM OF THE PENINSULAR REGION.

Introduction. Extent. Conditions of deposition. Thickness. Stratigraphical position. Peculiar distribution. Faulted boundaries. Accompaniments and complexities of the faulting. Extent of original deposition. Physiography. Subdivision. A. **Lower Gondwana**: Difficulties of classification; I. **Talchir series**: **Talchir stage**—General character—Boulder beds—Other peculiar types of rock—Thickness—Fossils—Mode of accumulation; II. **Damuda series**: Definition and thickness; Fossils and correlation; Lithology; Mode of deposition; Subdivision; Coal seams of the Damuda series; Fossil logs; The coal industry of India; Burnt outcrops; (*a*) **Karharbari Sub-stage**—Classificatory position—Lithology—Distribution—Plant remains—Umaria occurrence; (*b*) **Barakar stage**—Lower boundary—Thickness—Lithology—Flora; (*c*) **Ironstone Shales**; (*d*) **Raniganj stage**—Damodar valley, Palamau, Sarguja and southern Rewah—Areas outside the Damodar valley—Pali stage. **Lower Gondwanas of the Satpura area**; Succession; Motur stage; Bijori stage; " Almod beds ". **Lower Gondwanas of the Mahanadi basin. Kamthi beds of the Wardha-Godavari basin. III. Panchet series and its equivalents**; **Panchet series of Bengal and Bihar**; **Mangli beds of the Wardha valley**; **Parsora stage of Southern Rewah. Lower Gondwanas of the Garo Hills, Assam. B. Upper Gondwana**: General relationships; **Mahadeva series**: **Mahadeo Hills or Satpura region**—Distribution, structure and sub-division—Pachmarhi stage—Denwa stage—Bagra " stage ". **Godavari valley. Southern Rewah and Northern Sarguja. Mahanadi valley. Damodar valley and Country in a line to the west**: Tatapani; Hutar: Aurunga; Karanpura; Bokaro; Raniganj; Rajmahal hills. **Rajmahal series. Basic intrusive of the Damodar valley and other parts**: Two phases; Mica peridotites; Dolerite and basalt. **Sylhet Trap. Kota and Chikiala stages of the Godavari valley.** Kota; Chikiala. **Jabalpur series**: Satpura region; South Rewah and Korea; Kathiawar. **Narha beds of Cutch. Umia Plant Beds of Cutch. Ahmednagar Sandstone of Idar. Katkot sandstones of the middle Narbada. Nimar sandstone of the Lower Narbada. Wadhwan Sandstone of Kathiawar. Upper Gondwanas of the East coast**; Coastal character; Distribution; Athgarh Sandstone of Cuttack; Ellore area; Ongole area; Madras area; Trichinopoly area; Age of the East Coast beds. **Gondwanas of Ceylon. Gondwanas of western Rajputana**: Bap boulder bed; Lathi series; Barmer Sandstone. **Gondwana equivalents in Afghanistan**: Saighan series. **Gondwana equivalents in Burma.**

Introduction.—The Upper Palæozoic and all but the upper stages of the Mesozoic sequence in other parts of the world are represented in the Indian Peninsula, as they are in many other countries of the southern hemisphere, by a great succession of beds composed chiefly of sandstones and shales which, except for some exposures along the east coast and one exposure in southern Rewah, appear to have been entirely deposited in fresh water; whether the east coast exposures should be included in the term Gondwana has recently been questioned by the author. Remains of animals are rare in these rocks, and the few which have been found belong to the lower vertebrate classes of reptiles, amphibians and fishes, with the addition of the phyllopod *Estheria*, and a few molluscs. Plant remains are much more plentiful, and evidence of several successive floras has been detected. It is by its plants that this vast range in time can be divided into two principal periods, an older characterised by the classic *Glossopteris* flora, and a younger distinguished by a cycadaceous *Ptilophyllum* flora. The subdivisions of this great plant-bearing sequence were at first described under a number of local names of which the oldest and best known are: Talchir, Damuda,[1] Panchet,

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[1] More correctly Talcher and Damodar, but the spelling in the text has become stereotype by long usage for these geological subdivisions.

Mahadeva, Rajmahal and Jabalpur, but the now well-known term, Gondwana, has for many years past been adopted for the whole sequence. The significance of the expression is more that of an era than of a system ; the Gondwana formation, in fact, is astride no less than five of the European systems, covering a similar number of Dr. Arthur Holmes' 30-million-year cycles and in this way corresponding to a total of over 150 million years. It began with a glacial period in Upper Carboniferous times and closed soon after the beginning of the Cretaceous period. On account of its rich coal contents, which are mostly confined to its lower portions, this system—for a system it is convenient to call it—was one of the first to receive geological attention, and was, in fact, mainly responsible for the inception of the Geological Survey of India in 1851. From the recent re-survey of the Indian coalfields by Sir Cyril Fox and his party, and from still later discoveries, the substance of this chapter has been brought up to date. The term, Gondwana, is derived from the old name for the countries south of the Narbada valley, which were formerly kingdoms of the aboriginal tribe of Gonds and today spread over much of the Central Provinces. It is in this region of the Gonds that the most complete sequence of the formation under consideration is to be found.

Extent.—As a whole, the Gondwana system has a wide extension in the Indian Peninsula. The majority of its outcrops are concentrated within a tract bounded on the north by the valleys of the Narbada and the Son and on the south by a line drawn from the sea at Masulipatam through Khammamett and Warangal, and entering the Trap area near Nirmal, a town in the north of Hyderabad State ; outside these limits the system occurs in smaller exposures. Some rocks containing plant remains and underlying Jurassic limestones in the desert between the Indus and the Aravalli range closely resemble portions of the Gondwana sequence in lithological characters ; representatives of the highest Gondwana groups are found in Cutch, resting upon marine Jurassic rocks and capped by Lower Cretaceous (Aptian) beds ; and what have in the past been referred to as members of the higher Gondwanas—in this case frequently containing marine fossils of Lower Cretaceous age—extend down the east coast. The best known outcrops of Gondwana rocks are in the Damodar valley and the Rajmahal hills of Bihar and Bengal, in the Feudatory States of Orissa, in Chhattisgarh, in Chota Nagpur, in the upper Son valley, in the Satpura range south of the Narbada valley, and in the Godavari basin. In the Extra-peninsular regions, the occurrences of this system are somewhat more limited but they have been detected in the Salt Range of the Punjab, in the Hazara mountains, in Kashmir, in the Simla States and Garhwal, along the base of the eastern Himalaya, and in one spot apparently on the Tibetan side of the Great Himalaya range ; in many of these localities, they include marine bands. All these Extra-peninsular occurrences have been described in the previous chapter. The equivalents of part of the Upper division of the system are present in the Shan States of Burma but, as they probably belong to a different palæobotanical life province, the term, Upper Gondwana, is applicable to them only in a taxial sense.

Conditions of Deposition.—Omitting the bands with marine fossils, which in a few cases interrupt or replace the Gondwana sedimentation and which though homotaxial with parts thereof, do not belong to the Gondwana facies, the whole of this great system is believed to consist of strata deposited in fresh water. The few fish and reptiles which occur might have inhabited either lakes or rivers, the phyllopod crustaceans, which are common in several of the subdivisions, might have lived either in lakes or in the extensive pools and marshes which often occupy so large an area in broad river valleys, while the plant remains are drift material which might have been preserved in either lacustrine or fluviatile deposits. At the same time, the coarseness of the rocks in general, the prevalence of sandstones, and the frequent occurrence of bands of conglomerate, render it improbable that these strata accumulated to any extent in normal lakes of any permanency. Other physical characters of the sediments, such as the frequent alternation of coarse and fine beds, the repeated occurrence of current-marking on the finer shales and of current-bedding in the coarser sandstones, and the local denudation of the upper portions of a bed such as a coal seam, so commonly seen where a coarse sandstone has been deposited thereupon, are all consistent with the theory of deposition in a river valley. Lacustrine conditions, however, probably prevailed at certain times in certain places. The Mahadeva basin, for example, seems to have occupied a lake during a large part of the Gondwana era. The sediments of this basin are thickest in the centre where they form the Mahadeo range, and thin out to the east and to the west; furthermore, they show no signs of texture-grading along the length of the basin from east to west, but are very noticeably graded at right angles to the length, *i.e.*, from north to south. The position of the Bagra conglomerates along the northern margin of the Mahadeva outcrops presupposes a rocky shore in this direction—a shore whose line was no doubt governed by the fault which, it is surmised, formed the approximate northern boundary of the basin.[1]

Over most of the Indian Peninsular area and during most of the Gondwana era, we may visualise a system of wide river valleys, typical of a highly matured drainage system, impressed upon a floor planed to an undulating surface by the action during the opening phase—a system of streams bordered and interrupted by extensive swamps which became transformed in periods of flood to temporary lakes. In such lakes accumulated the finer and more persistent sediments such as the finer sandstones, the shale and the coal seams, the last derived from a forest-clad catchment area. The silting-up of these lakes would have produced alluvial swamps in which the meandering river flung its gravels and coarse current-bedded sands. The nearest approach to these particular conditions in India today is perhaps seen in the *jhils* or swamps of Sylhet and Cachar, products of a heavy rainfall, an extremely moist climate and a drainage characterised by sections of very low gradient. Conditions of this kind, though probably not so extreme, prevailed probably throughout most of the Damuda period, but were succeeded by those of the Panchet climate which there is good reason to believe was an arid one. The Damuda sedimentation was preceded by the deposition of a glacial tillite which ushered in the Gondwana era and indicates the presence of vast ice sheets. During that part of the era which immediately followed this glacial age, ice-caps on the adjacent highlands would have supplied much of the flood-water which carried down the coarser deposits to the alluvial tracts below. The arid conditions of the Panchet seem to have persisted during the Mahadeva period in the Satpura region, but were replaced by a moister climate in the Rajmahal hills. In the Satpura region, the Jabalpur period was characterised by an increased vegetation, but not so luxuriant as that which flourished during Rajmahal times in the Rajmahal hills.

In facies, though not in time, the Gondwana, and especially the Lower Gondwana strata correspond to those of the younger Carboniferous of western Europe and the older Carboniferous of eastern Europe. Over the Indian Peninsular area conditions throughout the Gondwana era were generally quiescent except for the Rajmahal volcanic disturbance and a protracted localised faulting. There may have been slight changes in the coast-line, but these made no appreciable difference to the general distribution of land and sea in the Indian area throughout the era.

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[1] H. Crookshank. *Mem.*, LXVI, 269 (1936).

Thickness.—The maximum thicknesses of the Gondwana subdivisions total roughly some 20,000 feet—*i.e.*, 10,000 feet in the case of the Lower division, and 10,000 feet in the case of the Upper. The greatest total for the Lower Gondwanas of the Raniganj coalfield (including the Talchir, Damuda and Panchet series) is approximately this maximum figure ; in Jharia the original thickness, which probably included some sheets of basaltic lava, is estimated to have been nearer 12,500 feet. The greatest total for the Upper Gondwanas in the Satpura region (including the Pachmarhi sandstones) is not more than 10,000 feet.[1] Comparing the total amount of sediment with the total length of time, the rate of deposition appears at first sight to have been abnormally slow ; it is, however, necessary to remember that the sediments of this mainly fluviatile succession, were deposited intermittently, though perhaps rapidly throughout most cycles of deposition, with long periods of rest during which in some areas interformational erosion is likely to have occurred locally. The small amount of discordance between successive subdivisions of the Gondwana system does not necessarily mean that the period of time which elapsed between the various groups was of small duration. This lesson is sometimes to be learnt from the fossil contents of the rocks and it may be surmised that further subdivision might be practicable in such groups as the Kamthi or Pachmarhi if the strata possessed a greater number of fossiliferous horizons.

Stratigraphical position.—So far as the exposures of the Peninsula are concerned, the relations of the Gondwana to older and newer formations afford no precise information as to its stratigraphical position. In this region, no older fossiliferous deposits are known, if we except some obscure Cambrian or pre-Cambrian impressions in the Lower Vindhyan rocks and, wherever the Gondwanas are seen to rest upon any older formation, there is complete unconformity between the two. Exposures of the Upper Vindhyan and Gondwana systems are never adjacent to each other, and the latter has nowhere been found in contact with the former which is the next formation in descending order ; pebbles of Upper Vindhyan rocks, however, are occasionally found in the Gondwana sediments,[2] and there is no evidence for assuming that the gap between the two was not a large one. In the Pranhita-Godavari valley, the Talchir and Damuda formations to a large extent rest, unconformably, upon strata believed to belong in part to the Cuddapah and in part to the Kurnool (? Lower Vindhyan) series ; in the country south of Nagpur and in the Mahanadi valley near Sambalpur, the same members of the Lower Gondwana rest for short distances, with the same unconformity, upon beds assigned to the Cuddapah. In general, however, the Gondwana beds are found to have been deposited upon Archaean metamorphic rocks.

With regard to their upper limit, the Gondwana rocks of the Peninsula are but rarely covered at all by a higher formation if we except the Deccan traps and their associated Infra-trappean beds of the Lameta group which rest unconformably upon the various subdivisions of the Gondwana system from the lowest to the highest, in the Narbada valley and the Nagpur country. There are, however, four or five localities in the Peninsula where sediments with Cretaceous fossils rest upon or occur among Upper Gondwana beds. The first of these is in Cutch, where the Umia group, containing some fossil plants found also in the uppermost Gondwana beds of the Narbada valley, underlies a stratum containing cephalopods of Aptian age. The second is situated in the Narbada valley near Barwai, where Bagh beds (Cenomanian or Albian) rest unconformably upon representatives of the Upper Gondwana. The remaining localities are near the east coast. One of these is in southern India, at Utatur, north of Trichinopoly, where beds with plant remains not much younger than those of the Rajmahal flora underlie the Utatur group (Cenomanian), unconformably in some places but in others with no apparent discordance. Another locality is situated near Ellore, where the Upper Gondwana beds contain plants of much the same age as those at Utatur and where marine fossils of Lower Cretaceous (Neocomian) age occur in the higher layers. In two other east coast localities, one north of Ongole and the other around Madras, outcrops of beds spoken of in the past as Upper Gondwanas, have yielded the same plant assemblage very closely associated with marine fossils which have not been closely determined but which include ammonites probably of the same type as those which date the beds at Ellore ; the plant remains in that case would have to be regarded as derived. The continental conditions which prevailed to the west of this slightly shifting coast-line have persisted to the present day, a fact which makes it an arbitrary matter of convention as to where the upper limit of the Gondwana system should be drawn. It is convenient to make the upper limit of this fresh-water system the base of the Lameta which, although itself a predominantly fresh-water formation, is more closely associated with the Deccan Trap than with the plant bearing Gondwanas.

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[1] C. S. Fox. *Mem.*, LVIII, 103 (1931).

[2] W. T. Blanford. *Mem.*, IX, pt 2,10 (1872); *Man.* 1st Edit., 205 (1879).

In places, the area of Gondwana rocks concealed beneath the Deccan Trap must be considerable. There is, for example, reason to believe that the Gondwanas of the Chhindwara district extend for some distance northeastwards beneath the Trap of Seoni and Mandla, and in the Wardha region there is little doubt that these lavas cover a large tract of the sedimentaries.

A protracted re-examination of the plant remains from the Lower Gondwanas has resulted in the conclusion that the beds containing them are not to be assigned entirely to the Trias as Feistmantel suggested[1] in 1876, but range from the Upper Carboniferous to the end of the Trias. That the lowermost beds of the system with their plant remains fall within the Carboniferous is a deduction supported by the evidence of marine fossils in Australia and other parts of the world where the precise equivalents of the Gondwana system are recognisable and include the glacial boulder bed at its base. In India, the evidence is not quite so definite but, such as it is, it confirms the above conclusion. In the Umaria coalfield of southern Rewah, the discovery of a marine Lower Permian ("Permo-Carboniferous ") fauna in beds of Karharbari age, overlying the Talchir boulder bed, makes the Upper Carboniferous age of the latter practically certain. In Kashmir, *Gangamopteris* and other typical Lower Gondwana genera are found in beds below the Zewan, a series containing an assemblage of fossils which cannot be younger than Permian and which is probably Lower to Middle Permian in age.

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[1] *Rec.*, IX, 28-42 (1876).

In Kashmir, the *Gangamopteris* beds overlie the Agglomeratic Slate, a series containing marine fossils of Uralian age and not improbably including an equivalent of the Talchir boulder bed ; this favours the inclusion of the latte within the Upper Carboniferous and the allotment of the *Gangamopteris* beds to the Artinskian or Lower Permian. In Spiti, the believed equivalent of the Zewan series overlies a conglomerate which has been equated by some with the Gondwana boulder bed, but which is more probably Lower Permian. In the Warcha area of the Salt Range, the *Gangamopteris* flora has been discovered at the top of the Lower Productus Limestone, a subdivision referred on account of its marine fossils to the Lower Permian.[1] Below this is the Nilawan series, at the base of which is the ubiquitous glacial boulder bed ; the beds immediately above the latter have yielded a fauna unmistakably equivalent to one found about the middle of the Lower Marine series (Upper Carboniferous) of Australia. The above plant horizon has been met with in several other localities in the western Salt Range. Recently, some carbonaceous shales, 25-28 feet thick, separated by some 9 feet of sandstones and sandy shales from the Talchir boulder bed near Kathwai, a village in the western parts of the Salt Range, have yielded identifiable impressions of *Glossopteris* and other plants, together with a few small lamellibranch casts ; this occurrence is 700-800 feet lower in the scale than the Warcha flora, and is one of the lowest, if not the lowest, at which Gondwana plants have been found in India.

Peculiar distribution.—The manner in which the exposures of Gondwana rocks are distributed throughout the country is peculiar. As a general rule, these rocks are found occupying basin-shaped depressions in the older formations—depressions aligned in sets, each of which lies more or less closely along a river valley or what may have been a more ancient position of the same valley. Subordinate and isolated outcrops scattered over the surface of the neighbouring country are merely the undenuded remains of strata which were at one time continuous with those of the main basins and covered a much larger area. There is very little doubt that the isolated exposures in each single river valley also originally formed one continuous outcrop. The Damodar valley coalfields, for instance, are regarded as isolated remnants of an once continuous Gondwana exposure which stretched as an unbroken strip across the ancient land-masses of Bengal and Bihar and reached westwards as far as southern Rewah. On Panchet Hill in the Raniganj coalfield and on Lugu Hill in the Bokaro field, that is to say, east and west of the Jharia field in the Damodar valley, are found sandstones belonging to the Panchet and Dubrajpur series, each of which once formed a continuous sheet from Bokaro to Raniganj across Jharia.[2] The Rajmahal and Birbhum outcrops may once have joined up with the Damodar valley exposures. Of the Gondwana exposures of the eastern Himalaya we know nothing except that, like those of Kashmir and the Salt Range, they denote sediments laid down close to a coast. Mallet was of opinion that the Himalayan outcrops were at one time continuous with those of the Rajmahal hills.[3]

Although there are some grounds for assuming that the drainage along the old Damodar river flowed eastwards, it does not seem to have had its origin in the great watershed of the Aravalli range, for in a westward direction the line of the valley joins the vast Gondwana tract of Sarguja and southern Rewah whose western extremity was a coastal area at a very early period of the Gondwana era.

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[1] F. R. Cowper Reed, G. de P. Cotter. & H. M. Lahiri. *Rec.*, LXII, 424 (1929).

[2] C. S. Fox. *Mem.*, LVI, 23 (1930).

[3] Mem., XI, 32, 33 (1874).

This coastal area, with its marine fossils, intervenes, in fact, between the line of the Damodar valley and the Aravalli. The question is beset with difficulties but if the Damodar river of Gondwana times flowed eastwards, it must have risen from some portion of the ancient ridge of gneiss which occupied the Hazaribagh plateau and stretched thence westwards or W.S.W.' wards through Manda.

Two alignments of basins, similar to the alignment of the Damodar valley basins, are clearly discernible elsewhere, one along the Wardha-Godavari valley and the other along the valley of the Mahanadi and Brahmani. In these cases matters become still more involved, since the Mahanadi alignment meets the Damodar alignment in the large Sarguja-Rewah exposure. Not only do these two alignments converge upon the Sarguja-Rewah tract, but the latter is in all probability continuous to some extent beneath the Trap with the Satpura exposure of Gondwanas, and towards the latter converges also the alignment of the Godavari outcrops. The general convergence of all these alignments is not in itself incompatible with the idea of drainage towards the west and northwest in the direction of the old Rewah coast and the Satpura area, and this is the view favoured by Sir Cyril Fox in the case of the Mahanadi and Godavari.[1] At the same time, the main watershed of the Indian portion of the Gondwana continent must still have been the Aravalli range, some distance west of the Satpura region, and we know definitely that towards the end of the Gondwana era one of the coast-lines of Gondwanaland coincided closely with the present Coromandel coast. If the drainage of the Mahanadi and Godavari were ever northwestwards, therefore, it must have undergone a complete reversal during Gondwana times, a hypothesis which is not easy to accept. It seems at any rate equally justifiable to assume that the drainage of the old Mahanadi and Godavari was in the same direction as it is to-day, *i.e.*, towards the southeast, and that the distribution of watersheds was not a simple one. The ice-sheets of the Talchir epoch would have planed down many of the minor hill features of the country and have filled up many of the valleys with debris. The result might well have been a monotonously undulating country-side with marshes and lakes interspersed here and there and no marked drainage tendencies.

Faulted boundaries.—A conclusion now generally accepted is that all surviving basins whose outcrops are bounded by an abrupt line cutting them off on one side or both sides—and these, as will be seen, constitute a very large majority of the basins known—owe their preservation from denudation to a disturbance of their originally horizontal position and to their depression to a lower level than neighbouring portions of the same strata; in other words, their preservation is largely the result of faulting subsequent to the deposition of the beds concerned.

A few instances will suffice to illustrate the phenomena presented by these disjointed outcrops. In the Damodar valley, the detached basins of the Raniganj, Jharia, Bokaro and Karanpura coalfields extending in a straight line from east to west in low ground along the banks of the river—and, skipping the Aurunga field, one might add the fields of Hutar and Tatapani—all present certain peculiarities. In the first place, and in a general way, all outcrops are cut off abruptly along the southern edge; secondly, there is a general dip of the rocks from north to south; thirdly, the lowest subdivisions appear along the northern side of each basin; and fourthly, the abrupt southern boundary is a straight or nearly straight line coinciding with a fault of normal but somewhat complex character. Geological relations of a similar kind exist in many other areas. Thus, in the great basin of southern Rewah and Sarguja, and again in the Satpura area south of the Narbada, the rocks dip as usual from one side of the basin and are cut off on the other, but in these cases the general dip is to the north and not to the south, and it is along their northern border that the beds are abruptly truncated. The large fault along the northern margin of the Satpura area or Mahadeva basin seems to have marked a line along which a late fracturing was responsible for the formation of the Narbada valley, though both the fault and the fringe of Gondwana sediments to the immediate south of it are now concealed beneath the river alluvium ; whether any Gondwana beds were ever deposited over the tract now lying to the north of the fault, it is impossible to say, since the same alluvial deposits stretch for some distance in this direction. In some cases, notably in the northern part of the area occupied by so large a portion of the Godavari valley, both boundaries—in this instance directed nearly N.W.-S.E.—are straight, abrupt and nearly parallel ; they are obviously examples of trough faulting. The Talcher field is another instance in which the Gondwanas have been preserved in a trough between two boundary faults ; northwestwards, it is followed by another tract whose southern boundary is also a large northwardly-throwing fault. In the Giridih coalfield, there are three major faults, all parallel to one another, two forming the boundaries north and south, and the other extending down the centre.

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[1] *Mem.* LIX, 27 (1934).

The exact orientation of the abrupt boundary of Gondwana basins varies, but there is a tendency for it to remain approximately constant throughout each alignment or set of basins ; in other words, the faulted boundaries of adjacent basins in the same alignment are more or less parallel to or in line with each other. When the faults of two adjacent basins are in line with each other, traces of the dislocation can sometimes be made out in the intervening patch of metamorphic rocks, indicating an apparent continuation of the fracture from one basin to another. In such cases, however, it is important to note that the throw of such apparently continuous faulting reaches a maximum at the centre of each basin and may be relatively negligible across the intervening gneissic tract ; in other words, the faulting along each alignment of basins is of a switchback nature, the throw rising and falling at intervals whose frequency depends upon the number of basins along the alignment. This conclusion is warranted, not only from the linear arrangement of the faulted basins, but also from the basin-like or concentric distribution of the outcrops of successive Gondwana stages in each basin. There are even certain appositions of outcrops which are best explained on the assumption that a fault, when traced along its course, changes its direction of throw. The faulted boundaries of the basins are not always completely exclusive, and even the lowest members of the Gondwana formation are sometimes found as outliers outside the boundary fault, as, for example, in the Bokaro area, where small patches of Talchirs and Barakars occur beyond the northern faulted boundary.

Accompaniments and complexities of the faulting.—The faults just described are almost invariably accompanied by considerable disturbance of the beds in their neighbourhood, and are often marked by shearing, induration, silicification, and sometimes by brecciation ; this is well seen in the Raniganj field. Along the boundary of the Talcher field, and on the eastern portion of the northern boundary of the Sohagpur field, the plane of the fault is characterised by a breccia containing fragments of the Gondwana sandstones. Hot springs are connected with the faulting in the Aurunga and the Tatapani coalfields. The frequent intrusion of basic igneous rock along the fault-planes is a matter which will receive further attention. Additional evidence of the stresses which have imposed present structures on the rocks of the coalfields is seen in the veins of white cellular quartz which in places intersect the Talchir sandstones as well as the Archæan rocks immediately outside the limits of the fields;[1] to the northeast of Dhanbad, for instance, a noticeable ridge of gneiss traversed by vein quartz and situated in a line with the large fault forming the southern boundary of the Raniganj coalfield, is thought to mark a continuation of the fracture.[2] Sometimes one of these large faults can be seen to fork; along the northeastern edge of the Talchir field for example, the fault branches, and in the fork between the branches is exposed the Talchir or lowest Gondwana stage faulted on the one side against Kamthi beds which belong to much higher horizons of the Gondwana system, and on the other against Archæan gneiss.

There are various complexities in these boundary faults, which are hardly ever seen to be simple, clean-cut fractures. Sometimes the main fault is "stepped" by small cross faults; this is well seen in Raniganj where the abrupt southern boundary is in reality a series of large strike faults arranged *en echelon* and complicated by a number of cross faults.[3] In the lower portion of the Godavari tract west of Sironcha, the boundary is échelonned in a simpler manner by a series of three or four parallel strike faults. Faulting, sometimes on a considerable scale has occurred within the basins themselves and is a great drawback to coal-mining. In the Jharia, Bokaro and Karanpura coalfields, the greater amount of faulting in the western parts of each field has resulted in the Barakar coal seams having attracted less attention than they have in the eastern parts.[4] The coal seams of the Tatapani-Ramkola field have suffered severely from faulting. Many of the minor cross faults of the Indian coalfields appear to be mere adjustments of the more yielding strata to the major deformations. In the Karanpura field, many of the faults are described by Dr. Jowett as having a horizontal as well as a vertical component, and as suggesting "a kind of twisting or screwing effect".[5] The rapid way in which the Gondwana faults increase or decrease in throw or die out when traced laterally has been noted in the cases of the Giridih and Betul areas;[6] in the former field, some of them have been observed to change the direction of their hade in a short distance. There appears to be the same rapidity of change vertically, for faults in the lower coal seam of the Giridih field are sometimes not found at all or are found with a much smaller throw in the upper seam, which must mean that the displacements in the upper horizons have been distributed along more than one plane of movement.

The impression produced by a study of the complexities and irregularities that characterise the Gondwana faults is that the rocks yielded along lines not quite at right angles but somewhat oblique to the direction of the stress which produced them. In fact, the strike of the basins and of their faults seems to have been governed in many cases by the foliation or strike of the gneisses, schists and other rocks on which the Gondwanas lay, rather than by the precise direction of the earth movement which affected them. There is often a general parallelism between the basins, their alignment and faults, on the one hand, and the foliation or strike of the ancient rocks which form their floor, on the other. Sir Lewis Fermor has noted that the coalfields of Palamau and the Damodar valley are aligned in conformity with the average E.-W. Archæan strike. A similar conformity can to some extent be made out in the Mahanadi valley, where the direction is approximately W.N.W.-E.S.E., and in the Central Provinces, where it is E.-W. In the Godavari area it is the later rocks of the Purana (Vindhyan) or Kurnool system which cradles the Gondwanas, and the parallelism between the two is marked. It seems likely that the Gondwanas and the floor rocks on which they reposed responded to disturbing forces along the lines of least resistance, which would have been the foliation planes or joints of the older rocks. Such a conception affords a simple explanation of the appreciable difference in strike between the alignments of different sets of Gondwana basins and their fault systems, and makes it easier to understand some of the complexities in the latter enumerated above.

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[1] E. R. Gee. *Mem.*, LXI, 29 (1932).

[2] C. S. Fox *Mem.*, LVI, 14 (1930).

[3] E. R. Gee. *Mem.*, LXI, 24, 25 (1932).

[4] C. S. Fox. *Mem.*, LIX (1934).

[5] *Mem.*, LII, 141 (1925).

[6] W. Saise. *Rec.*, XXVII, 90-91 (1894); Gen. Rept., *Rec.*, LIX, 88 (1926).

Although the greater part of the dislocation, of which the faults are evidence, must have been caused by tensional stresses, the Gondwana strata have also been affected by compressional impulses sufficient to warp them into folds and to produce local thrusting and shearing.[1] In the Denwa-Pachmarhi basin of the Mahadeo hills, three or four anticlinal axes are discernible parallel to the faults.[2] On the whole, the tensional seem to have preceded the compressional stresses, but there appears to have been some oscillation between the two, for there is reason to suppose that, not only faulting of tensional origin but also plication, which is a compressional feature, commenced before the end of the Gondwana era. An example of the latter is quoted by Crookshank as occurring in the Mahadeo hills. Here a conspicuous northerly dip characterises the Bijori and Pachmarhi rocks, but is not marked in younger Gondwana (Jabalpur) beds and is rare in the flows of Deccan Trap; such a dip, therefore, must be due for the most part to post-Pachmarhi, pre-Jabalpur movement; some of the dips in the Bijoris, moreover, are not reflected in the overlying Pachmarhis.[3] Speaking generally, the Talchir rocks of this area, *i.e.* those belonging to the oldest of the Gondwana subdivisions, appear to be more considerably folded than those belonging to any of the higher stages of the system.[4]

On the assumption that faulting began before the end of Gondwana times can be explained certain peculiarities of the Satpura field, where some of the uppermost Gondwana beds overlap the faulted boundary and are obviously younger than the fault; along the northern boundary of this basin, however, there is in many places a complicated system of faults with downthrow to the north, and most of the dislocations are younger than the first flows of the Deccan Trap. Again, near the fault which bounds the northwestern edge of the Umaria coalfield in the State of Rewah, there is intensive overlapping by the "Supra-Barakar" beds on to the Karharbaris and finally on to the Talchirs; this overlap, which increases in the upper horizons of the Supra-Barakars, is not seen in the more remote parts of the coalfield. Gee's deduction is that the faulting in this area commenced previous to the deposition of the Karharbaris and continued more actively during Supra-Barakar sedimentation.[5] One of the clearest cases of faulting older than the Upper Gondwana sedimentation but younger than the Barakar epoch is observable in the Visrampur coalfield in the middle of Sarguja. Here, an interrupted strip of Talchirs along the south of the field is faulted to the north against Barakar beds, and along the south against Archæan gneiss and Barakars. Over part of this Talchir outcrop lies unconformably a patch of Upper Gondwanas, probably of Mahadeva age ; this patch not only covers the whole breadth of the Talchir strip but overlaps the northern fault on to the Barakars and the southern fault on to the gneiss. In the Chanda area, Fox concludes, faulting occurred after the deposition of the Chikiala beds, which are probably of late Jurassic age, and before the Infra-trappeans of Pisdura were laid down.

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[1] C. S. Fox. *Mem.*, LVI, 152 (1930),

[2] Gen- Rep., *Rec.*, LIX, 86 (1926).

[3] H. Crookshank. *Mem.*, LXVI, 217-218 (1936).

[4] *Ibid*, 210.

[5] *Rec.*, LX, 400 (1927).

Evidence is clear, therefore, that in any one set of Gondwana basins, the faulting was not always confined to one particular plane of fracture, nor was it always restricted to one particular time phase. At the same time, much of the dislocation undoubtedly took place towards the end of the Upper Gondwana period, *i.e.*, in late Jurassic or early Cretaceous times, and it is not improbable that movement along these planes of fracture lingered into the Tertiary era.

It is interesting to note that a direction somewhere between N.-S. and N.E.-S.W. for the stresses which affected the Gondwana rocks fits in well with the average orientation of the sets of Gondwana basins and their major faults, and that along a similar direction the great Himalayan movement commenced, if not before, certainly not very long after the end of the Gondwana era. Most of the major Gondwana faults were initiated, it is presumed, long before the commencement of the Himalayan movement, but the old planes of fracture may well have served for any additional dislocation which the Himalayan movement is likely to have caused. The fact that many of these planes were not quite at right angles to the direction of this later stress may account for the "twisted or screwed" condition of the rock in contact with some of the faults, for the staggered fracturing, for the step-faulting, and for other complexities. It was no doubt the later stress which alternated between tension and compression. The Himalayan movement was one of compression, caused by the northward drift of the Indian Peninsula in the direction of Tibet. On the other hand, the Gondwana faults are for the most part of normal type, and therefore initially and essentially tensional phenomena, though some of them may have been reversed subsequent to their initiation. The presence of tensional fracturing as an accompaniment to compressional movement at first sight seems contradictory, but may perhaps be explained in the following way, in the language of the continental drift theory. While the northern edge of the northwardly-moving Gondwana continent became buckled up with the Tethys sediments, and a deep belt of down-warping behind this buckled margin produced the Indo-Gangetic trough, another broad belt behind the trough, embracing most of the Peninsula, must have suffered a broad parallel upwarp. The effect of such an upwarp, extending across the breadth of the Peninsula, would have been a tension in the more superficial layers and the ultimate production of fissures deep enough presumably to tap the underground reservoirs of the Deccan Trap magma. This upward warping and its subsequent partial and intermittent subsidence might explain some of the peculiarities in hade and throw of the Gondwana faulting. It can hardly be expected that the mutual approach of the Gondwana and Angara continents could have taken place without a certain amount of deformation and disturbance within the continental *massifs* themselves. Upwarping of epeirogenic proportions is known to have occurred in the Angara continent, and basic lava flows of the widespread Trap formation of Siberia are said to have begun in the Cretaceous and to have continued during the Tertiary period. The Gondwana faulting may have been facilitated by intermittent recoils which one continent drifting against the marginal sediments of another might be supposed to make during its invasive progress. The faulting which preserved the Gondwana basins in India appears to have no close parallel in South Africa, where there is no structural equivalent of the Himalaya and where no extensive faulting seems to have taken place till Middle Cretaceous times.

Extent of original deposition.—Some of the above considerations lead up to the question whether deposition was limited to the river valleys where remnants are now seen, or whether the surviving Gondwana occurrences are portions of a continuous outcrop which covered a large proportion of the Indian Peninsula and stretched beyond it in certain directions. On *prima facie* grounds, the deposition of a system of such great thickness along riverine belts could scarcely have had the narrow limits it exhibits to-day. Such an idea is tenable only on the assumption that local subsidence along one side of each major fault commenced with the Gondwana era itself and continued *pari passu* with the accumulation of its sediments. The main feature against this hypothesis is the order in which the various stages of the system crop out, the youngest next to the fault and each older stage following in more or less regular successive belts away from the fault until the lowest is seen forming the margin of the field—an irregular margin because of the unevenness of the floor of ancient rocks on which it unconformably lies. Had faulting and the local subsidence consequent thereon been continuous throughout the whole era, or taken place principally during the earlier epochs, the result would have been a regular successive overlap of the various stages away from the fault, but, while such successive overlap is not uncommon among the Gondwana stages, it bears no constant relationship to the faulting. Allowing for the fact that the total thickness of some 20,000 feet of strata is an aggregate of maxima and must be far in excess of the total deposition in any one spot, we should expect the Gondwana deposits, previous to the enormous amount of denudation they must have subsequently undergone, to have covered a much larger surface of the Peninsula than they do now, and there is evidence that they did so in the presence of outliers outside the main outcrops. Both Talchir and Damuda beds, for example, are found on the Hazaribagh tableland, immediately north of the Damodar valley, at a height of about 1,000 feet above the surface of the same rocks in the valley itself; since the throw of the fault in the Jharia basin is 5,000 feet and in the Raniganj basin as much as 9,000 feet, it seems possible that the difference in level is due entirely to the faulting. The dip in the Jharia field if prolonged northwards would pass the Gondwana rocks over the gneissic top of Parasnath Hill, which is 4,480 feet above sea-level,[1] *i.e.*, between 3,700 and 3,800 feet higher than the average elevation of the coal basin.

To admit that the Gondwana formation at the end of its deposition covered an area many times as great as that to which its outcrops have since been reduced by denudation, is, however, not to presuppose that their outcrops were continuous over the whole of the eastern or any other portion of the Indian Peninsula or over the Archæan tracts which now separate the lines of basins. There is no reason to believe, for instance, that the Gondwana deposits of the Mahanadi valley were ever continuous across what are now the Eastern Ghats with those of the Godavari, nor is there any evidence to show that the Mahanadi outcrops were ever united with those of the Damodar valley over the uplands of Bonai, Keonjhar, Mayurbhanj and Singhbhum. The magnitude of the overlap which often characterises successive Gondwana stages is evidence against deposition on such a widespread scale. Stages of the upper division of the system, for instance, are in many places to be seen lying directly upon the gneissic and other ancient rocks; where two such occurrences are separated from each other by lengthy tracts of elevated country bare of Gondwana outliers except in the immediate neighbourhood of either Gondwana basin, it is logical to conclude that the lower stages at least were never continuous across the intervening tract which has persisted to the present day as a watershed. The coincidence of the modern river valleys with lines of Gondwana outcrops teaches us nothing conclusive in this respect, for it might be due simply to the fact that the Gondwana beds, being much softer than the surrounding Vindhyan, Cuddapah or Archæan rocks, have been selected by the rivers as their easiest channel to the sea; in other words, the existing drainage of the east coast, so far as it coincides with the distribution of the Gondwana rocks, might have been determined merely by the disposition of those rocks produced by disturbance and denudation, and may have no necessary connection with their original areas of deposition.

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[1] C. S. Fox. *Mem.*, LVI, 20 (1930).

The most accurate picture of Gondwana conditions is probably a compromise between two extreme views, and leads to the conclusion that deposition during Gondwana times was restricted to certain broad and extensive valleys, two or three of which can be recognised today in the surviving remnants of river silts whose distribution is interpreted by some as indicating an easterly or south-easterly course towards the open sea which we know covered Burma. Assuming that the Gondwana sediments were for the most part deposited by rivers, it is only natural to expect some concentration of such deposits along lines representing the courses of the rivers. The straightness of the Gondwana belts and their invariable disturbance by faulting parallel to the general direction of the belt suggest, in the first place, that the rivers had a generally straight trend and secondly, that the faulting or fracture commenced before the deposition of the earliest Gondwanas and, in fact, provided a line of easy erosion for the initiation of the rivers. Had the faulting been entirely subsequent to and independent of the Gondwana sedimentation, we might expect some of the fluviatile belts to be devoid of such disturbance, just as we might equally expect to find lines of faulting and fracture outsside the country occupied by the Gondwana belts.

In reviewing the course of Gondwana events, we start with the movement of the glaciers and ice sheets of the earliest Gondwana epoch over a land area possessing a more or less matured drainage system. It is not to be supposed that this drainage system was obliterated, or the relative position of valleys and highlands appreciably altered, by the Talchir ice sheets whose chief effect must have been to plane down the smaller and sharper physiographical prominences of the valleys down which they moved, scouring their surface into the uneven hummocky floor which is so characteristic of the basal limit of the formation. The river silts which followed the melting of the ice were presumably deposited in the same broadened and débris-filled valleys, the earliest deposits sometimes around "islands" of metamorphic rocks, as for example in the Karanpura area. The major faulting took place in interrupted sections along these valleys, and the locus of deposition was preserved, chiefly by the continued faulting but partly by the easily eroded basins of soft sediment so preserved. An acceptance of this tentative reconstruction would lead to the conclusion that many of the valleys of today were there from the commencement of the Gondwana era and have probably swerved to no marked extent from their original alignment. The greater part of the original gneissic floor of each valley, on the downthrow side of the faulting, now lies buried beneath thousands of feet of sediment; in valleys like the Damodar, it rises and falls along the downthrow, sinking in some of the basins to a depth of several thousand feet below present sea-level.

Physiography.—The tracts of country occupied by rocks of the Gondwana system are, as a rule, covered with a poor sandy soil ill suited for cultivation the result being that in many parts of India they form wild uninhabited forests. The Upper Gondwana rocks are principally sandstones and decompose readily into loose sand which covers the surface and conceals the country rock beneath.

Subdivision.—Remembering that the Gondwana sediments were laid down in fresh water, either by large rivers swinging from one side of the wide valleys to the other, or in temporary lake basins fed and drained by the rivers, it is not to be expected that synchronous deposition was of the same kind in the various basins. For this reason, the groups of which the system is composed vary greatly, both as regards number and mineral character, in the several more or less isolated areas in which they are found, the variation being much greater amongst the middle and upper than amongst the lower members of the formation. The only generalisations that can be made with any degree of safety are that, whilst in many cases the upper stages are composed chiefly of coarse sandstone, grit and conglomerate, the two lowest, the Talchir and Barakar, consist largely of shales and preserve their mineral character almost unchanged throughout the area in which the Lower Gondwana beds are known to occur.

The system may be divided into a Lower and an Upper division, the distinction having been first established in western Bengal and Bihar, where it is of a trenchant nature, characterised by a marked stratigraphical discordance, by an almost complete absence of any plant species common to the two divisions, and by a pronounced change in the type of the flora. Equisetaceous plants prevail in the Lower, and cycads and conifers in the Upper division, while ferns are common to both. Some Equisetaceae, it is true, occur in the Upper Gondwanas, and several species of cycads and conifers in the Lower, but the genera are in most cases distinct in the two divisions. The break took place at the end of the Triassic (Panchet) period. The *Glossopteris* flora, which began to flourish in Talchir times (Upper Carboniferous) and became so typically developed in the Damuda series (Permian), gave place after the Panchet period to the Rajmahal or *Ptilophyllum* flora of the Upper Gondwanas, the labyrinthodont fauna ranging across the break.[1] This change corresponded with a change in climate. The *Glossopteris* flora, which flourished in a damp, comparatively cool climate, faded during the warmer, arid conditions of the Panchet period and had practically disappeared before the age of the Maleri (? Rhætic) reptiles. Over a large section of the Mahadeo, one of the Satpura ranges, Crookshank records a marked break between the Lower and Upper Gondwana, indicated by a sudden change in the nature of the organic remains; in some parts of this area, however, there is no sign of a stratigraphical unconformity between the two.[2] In south Rewah, the stratigraphical break is said to be not well marked, and floras bridging to some extent the gap in Bihar and western Bengal have been found.

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[1] *Vide* C. S. Fox. *Mem.*, LVIII, 7 (1931).

[2] H. Crookshank. *Mem.*, LXVI, 209 (1936).

The following table (p.924-925) depicts the general sequence and the mutual representation of the various subdivisions in different parts of India; from what has been said above, it will be readily understood that some of the subdivisional boundaries are to a large extent artificial and of little more than local value. In this work, Sir Cyril Fox's classificatory scheme has been adopted with minor modifications, the chief being that the Parsora stage has been given a place within the Panchet series, to some part of which it may correspond if all the plant remains attributed to it come from the same group.[1]

A. LOWER GONDWANA.

Difficulties of classification.—The *Glossopteris* flora ranges from the Talchir (Upper Carboniferous) to the end of the Panchet period (Trias), *i. e.*, to the end of the Lower division of the Gondwanas.[2] The uncertain phytological position of so many of the fronds and other vegetable relics, including such typical and abundant forms as *Glossopteris* itself, *Vertebraria*, *Gangamopteris*, *Sphenopteris*, *Pecopteris* and others, adds an element of difficulty and inconclusiveness to the scheme of classification adopted for the Lower division.[3] Several of the names retained in this work for convenience are suspected of being synonyms for the same plant. *Vertebraria*, for instance, is almost certainly the rhizome of *Glossopteris*, a name which has been applied solely to leaf fronds.[4] The fruit, *Samaropsis*, so called on account of its resemblance to the winged "samara" of the modern elm, has been found in the Talchir, Karharbari, Raniganj and Panchet stages in association with the leaves known as *Cordaites* (*Noeggerathiopsis*) and *Gangamopteris*, though never in direct organic connection with either; it is quite possibly the fructification of one of these two forms.

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[1] Dr. Cotter, in his revised scheme (*Rec.*, XLVIII, 23 (1917)) prefers to draw the boundary between the Lower and the Upper Gondwana a stage higher up, *i. e.*, a little further from the line of division between the Palæozoic and Mesozoic. In the present state of our knowledge and in view of the rarity of plant remains in the disputed stage, there is very little to choose between the schemes of Dr. Cotter and Sir Cyril Fox. The provisional adoption of the latter has been made chiefly because it tallies more closely with the old scheme and for that reason avoids confusion in statements regarding the Upper and Lower divisions of the system, especially statements concerning organic remains. It is, moreover, the most recent scheme evolved as a result of an extensive and protracted re-survey of the Indian coalfields.

Dr. Cotter's scheme would place the Maleri and Tiki beds, and therefore also the Denwa-Bagra beds at the top of the Lower division instead of at the base of the Upper. Since the Pachmarhis are closely associated with the Denwa-Bagra sequence and if anything, are older—they would also have to be brought down into the Lower Gondwanas and correlated presumably with the Panchet series. Possibly the Dubrajpur beds of the Rajmahal area and Damodar valley would also have to be brought down into the Lower division, in such a scheme.

[2] The reported occurrence of a few specimens of *Glossopteris* in the Jabalpur series near the top of the Upper division in the Satpura, accompanied in the same piece of rock by *Ginkgoites lobata* and *Cladophlebis denticulata* ("*Alethopteris Asplenium whitbyensis*") is almost certainly a mistake. *Pal. Ind.*, Ser., XI, Vol. II, Pt. 2, p. 90 (1877).

[3] *Vide* B. Sahni. *Proc. 8th Ind. Sci. Congr.*, *J. A. S. B.*, New Ser., XVII, No 4, Table facing p. clii (1921).

[4] M. R. Zeiller. *Rec.*, XXX, 43 (1897); R. D. Oldham. *Ibid.* 45 (1897).

	Europe.	General sequence in India.	Rajmahal Hills.	Birbhum, Deogarh and Giridih.	Damodar Valley.	Son, Mahanadi and Brahmani valleys.	Satpura region.	Godavari Valley.	East Coast.	Cutch and Kathiawar.
Cretaceous.	Aptian.								Tripati, Pavulur and Sattavedu.	(Marine Ukra beds).
	Neocomian.								Ragavapuram, Vemavaram, Sripermatur, Budavada.	
		Umia Plant beds.								Umia Plant beds. (Umia marine beds).
Jurassic.		Jabalpur.				Jabalpur.	Jabalpur.	Chikiala.		
		Mahadeva. Rajmahal.	Rajmahal Traps.				Mahadeva. Bagra.	Kota.	? Utatur Plant beds.	
			Rajmahal Plant beds.				Denwa.		Athgarh. Golapilli.	
	Rhætic.		Dubrajpur.		Dubrajpur.	Tiki.	Pachmarhi.	Maleri.		

Trias.	Panchet.			Panchet.	(? Tiki).		(? Maleri).		
					? Parsora.		Mangli.		
Permian.	Damuda.			Raniganj.	Pali and Hingir.	Bijori.	Kamthi.	Chintalpudi and Dummapett.	
				Ironstone Shales.	*...unconformity....*	Motur.			
		Barakar.	Barakar (including Karharbari).	Barakar.	Barakar (including Karbarbari and Umaria marine bed).	Barakar (Karharbari).	Barakar.		
Upper Carboniferous.	Talchir.	Talchir.	Talchir.	Talchir.	Talchir.	Talchir.	Talchir.		

more probably of the latter. There is reason to believe that *Cordaicarpus*, a similar fruit with a narrower wing, is connected with the peculiar scale-like organs described under the name of *Arberia indica*, and that both may belong to the plant which bore the fronds known as *Cordaites ; Arberia*, in fact, might well be the sporangia-bearing frond corresponding either to the sterile fronds known as *Cordaites* or to fronds of a similar barrenness termed *Gangamopteris*.[1] Some of the tree stems included in the term *Dadoxylon* may also have borne the *Cordaites* leaves, and are associated especially with the leaf, *C.* (*Noeggerathiopsis*) *hislopi* Bunb.[2] All the really valuable coal seams of India are found in the Lower Gondwana beds, chiefly in the Barakar stage.

I.—TALCHIR SERIES.

The lowest member of the Gondwana system is known as the Talchir, a series named after the small State of Talchir, one of the feudatories of Orissa, where it was first clearly distinguished. It is overlain, sometimes with a recognisable unconformity, by the Damuda series, and consists of a single stage, the Talchir stage. In earlier schemes of classification, the Talchir series was made to consist of the Talchir stage below and the so-called Karharbari stage above, but the latter appears to have more in common with the Barakar and is here included therewith.

TALCHIR STAGE.

General character.—When present—and it is nearely absent over any large Gondwana area—the Talchir stage, one of the most interesting rock groups of India, forms the base of the Gondwana system, the bulk of its rocks consisting of fine silty shales and mudstones, and fine soft sandstones. The shales are usually of a greenish grey or olive colour, rarely dull red, sometimes slaty, exceedingly fine in texture, and traversed by innumerable joints. These joints produce the extremely characteristic feature of " needle shales ", the rock breaking along them into thin, minute, angular fragments, typically elongate or acicular, which cover the surface of the ground. Not infrequently the shales and mudstones are somewhat calcareous, and in some places large concretionary masses of impure carbonate of lime have been found amongst them. In the Korba coalfield of the Central Provinces, Fermor records the frequent presence of thin courses and ovoid masses of fine-grained secondary limestone interbanded with the Talchir shales[3]. The fine silts of this sub-division are remarkably persistent in character throughout an immense tract of country.

The most characteristic sandstones are soft, fine and homogeneous in texture, composed of quartz and undecomposed pink felspar ; in colour they are pale greenish grey, buff or flesh-coloured. They are frequently somewhat massive, but are just as commonly interstratified in thin layers with the shales. In many places where exposed on the surface, they break up into polygonal fragments, three or four inches across, whence they have been called tesselated sandstones. These beds pass into coarser sandstones of less marked character, which vary, in colour and are sometimes conglomeratic. Contrary to what is a usual sequence it is the beds of finest texture—the shales—which are found at the base of the

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[1] A. C. Seward. " Fossil Plants ", Vol. II, 517 (1910).
[2] *Ibid*, Vol. III, 248.
[3] *Mem.*, XLI, 167 (1914).

Talchir stage, and the sandstones which are higher in position, the coarser sandstones, moreover, overlying those of finer texture. The upper portion of the Talchirs may, in fact, consist almost entirely of sandstones, often pebbly, especially where the stage passes gradually up into the Barakar ; these uppermost sandstones, purple, brown and white in colour, are often current-bedded, and weather into large " pillows " by a process of desquamation frequently independent of the original bedding-planes.[1] Some of the flags and shales are ripple-marked, and animal footprints have, in more than one case, been suspected.[2]

A thin coal seam has been recorded amongst the Talchir beds in the Jhilmili field of Sarguja but, as a rule, the stage is distinguished by the absence of coal and even of carbonaceous shale.

Two noteworthy features of the Talchir beds are : their power of resisting disintegration and, provided they are not covered by alluvial deposits derived from other rocks, the complete barrenness of the ground where they appear at the surface, a natural consequence of their inability to form soil on decomposition. In many places along the edges of the coalfields, where the Talchir beds occupy the ground, it is possible to walk for miles through very sparse, grassless jungle, over a surface composed entirely of the finely comminuted greenish grey shales.

Boulder beds.—The most interesting feature of the Talchir stage is the frequent occurrence amongst the shales and fine sandstones, generally towards the base of the stage but quite often some hundreds of feet above the bottom, of pebbles and boulders, always rolled and usually well rounded, varying in size from small fragments less than an inch across to huge blocks fifteen feet in diameter and thirty tons in weight ; blocks 30 or 40 feet in diameter are reported to occur in the Talchir boulder bed of the Tatapani coalfield in Sarguja. A common size is from six inches to three feet in diameter. Some of the larger boulders, though always water-worn, are sub-angular and irregular in shape.

The lateral distribution of the boulders is most capricious. In some parts of an area occupied by Talchir beds, none is to be found over many square miles of country ; more generally the boulders are met with at intervals and occasionally large numbers are crowded within a limited tract. The boulders consist of gneiss, granite, quartzite, shale, slate, rarely of hornblende schist and other types. Many of them can be matched among the local Archæan rocks, but in numerous cases they cannot, and there is every probability that these particular boulders at least have been transported from a distance, no rocks of similar character being found in the neighbourhood. In the Jharia coalfield, for instance, certain quartzite boulders are suggestive of the Vindhyan rocks of Central India and the Mirzapur country. In the Raniganj basin, among boulders of the local metamorphics, W. T. Blanford found pebbles of semi-quartzite, of greenstone and, in one case, of pyritious clay-slate, all of them foreign to the immediate surroundings.[3] In the Jhilmili coalfield of Sarguja, the boulder bed includes numerous examples of the characteristic compact Vindhyan sandstone or semi-quartzite, the nearest exposure of which is seventy or eighty miles away to the north. The same Vindhyan quartzite-sandstone, as well as Vindhyan limestone, figures among the boulders found in the Talchirs of the Kamthi outcrop in the Central Provinces.

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[1] E. R. Gee. *Mem.*, LXI, 31 (1932).

[2] W. T. Blanford *Mem.*, III, 38 (1861) ; C. S. Fox. *Ibid.* LVI, 27 (1930).

[3] *Mem.*, III, 38 (1861).

The Talchir deposits of Korea State include pebbles and small boulders of red jasper breccia which might have come from the Bijawars, as well as Vindhyan fragments, some of them recognisably of the Upper Rewah Sandstone and others possibly from the Kaimurs.[1] If only one or two such cases had been observed, it might be supposed that the parent rock from which the blocks were derived had formerly existed in the immediate vicinity and had been removed by denudation, but the cases in which there is reason to believe that the rounded blocks have been transported from afar are so numerous that this theory cannot be accepted. The boulders, it should be remembered, are found embedded in silt which is frequently of the finest texture. It is evident that deposition from water in rapid motion is here out of the question, since any stream capable of moving and rounding the boulders would have swept away the fine silty matrix in which they now lie. Even without further evidence, the suggestion which most satisfactorily accounts for their presence and association is that they were first rounded by torrents and then transported to their final position by ice. Fortunately, there is ample confirmation of this in the smoothed, polished and striated surfaces which are to be seen on some of the larger blocks in several localities ; according to Fox, this is especially the case with boulders of the relatively softer rocks such as granite and arenaceous shale or slate.[2] Where the matrix of the Talchir Boulder Bed has become softened by weathering, the bed with its boulders set at all angles and some of them ice-scratched, closely resembles a recent boulder clay.[3] Cases of striated and polished boulders are especially numerous and perfect in the Singrauli coalfield of southern Rewah.[4]

The Boulder Bed seldom exceeds 100 feet in thickness and is usually less than half this figure ; although such a characteristic feature, it forms but a relatively small proportion of the Talchir stage. To obtain a true sense of the proportion and the significance of the Boulder Bed, it is important to grasp this fact, and to remember that by far the greater part of the Talchir stage is made up of ordinary sub-aerial sediments. The size of the Boulder Bed is small compared with that of the corresponding Dwyka Tilite of South Africa, and the repeated recurrence of glacial conditions from Upper Carboniferous to Lower Permian times in Australia has no counterpart in India, where the glacial epoch was solitary and short-lived.

Sir Cyril Fox notes that, although there is little doubt as to its glacial origin, the Talchir Boulder Bed does not always represent undisturbed moraine material in parts of the Damodar valley, there are faint indications of bedding, witnessing to the fact that the moraine debris has in places been carried, probably not far from its original site, turned over by floods, and to some extent water-sorted. In the Karanpura area, Jowett describes a section in which the boulder bed forms an irregular mass partially enclosed by a roughly-bedded sandy conglomerate of a different and presumably more normal type.[5] In the great majority of cases, the Boulder Bed shows no sign of stratification.[6]

Polished and grooved glacial " pavements " beneath the Talchir deposits are not very common. A good example is seen in the strongly striated, grooved and polished rock-surface of Vindhyan limestone, underlying the Talchir boulder bed with its frequently scored and well polished boulders on the banks of the Penganga tributary just above its confluence with the Wardha river, about ten miles W.S.W. of Chanda in the Central Provinces ; polished metamorphic surfaces are also recorded near Podadih in the Raniganj coalfield,[1] and less certainly north of Suranga in the Jharia field.[2]

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[1] L. L. Fermor. *Mem.*, XLI, 167-168 (1914).

[2] *Mem.*, LVI, 24 (1930).

[3] A. Jowett. *Mem.*. LII, 12 (1925).

[4] Anul. Rep. *Rec.*, XXX, 4 (1897).

[5] *Mem.*, LII, 9 (1925).

[6] C. S. Fox. *Mem.*, LVIII, 225 (1931).

Other peculiar types of rocks.—A peculiarity of some of the Talchir rocks worthy of note is the remarkable resemblance occasionally presented by the more compact forms of shale to a consolidated volcanic ash, and by a variety of the sandstone to a decomposed basalt, both in colour and mode of weathering. South of the Penganga river, a peculiar rock has been noted by Fedden in the Talchirs near Charli, and again in the Khairgaon watercourse west of Nandgaon. It is a sandstone consisting of rounded grains of quartz with a little felspar, whose calcareous cement has assumed the form of ophitic, crystalline masses some quarter-of-an-inch across.[3] These ophitic crystals have been irregularly attacked by weathering and the rock has been split up into a number of irregular aggregates, each aggregate composed of sand grains and calcite ; these aggregates, though separated from each other, are held together by the interlocking of their irregularities, the result being a rock which has a certain amount of flexibility and is analogous to the type known as " itacolumite ".[4]

Thickness.—It is remarkable that a series of beds, occurring at large and disconnected intervals of space, should preserve such a constant and unique lithology throughout the immense tract over which they are scattered. The thickness of the Talchir stage varies greatly even in the same basin, a result due partly at least to the unevenness of the ancient floor upon which they were laid down ; pebbly sandstone of Talchir age has been noted within ancient cracks in one of the gneissic inliers of the Karanpura coalfield. Nowhere does the thickness of the stage exceed 1,000 feet. In the Raniganj coalfield, where fully developed, the stage is 900 feet ; where best exposed in Jharia, it is 800 feet. In the former area, the Talchirs are well represented in the north-west of the field where they appear to pass up into the Lower Barakar, but to the east, and again to the southwest, they die out comparatively rapidly ; similarly in Jharia, the Talchir outcrop diminishes in a northeasterly direction and is overlapped by the Barakar. In the type area of Talcher State the thickness of the stage is probably 500 feet, in the Aurunga coalfield of Bihar it has a maximum of 300 feet, and in the Bisrampur field of Chhattisgarh it is only some 200 feet. In some places as in Karanpura, the Talchir beds can be seen to have suffered denudation before the deposition of the overlying beds. In the Tatapani area, for example, Barakar silt has been recognised filling up old pot holes on a denuded surface of Talchir rocks, while in the Singrauli field, rolled pebbles derived from the Talchirs occur in a conglomerate of a Barakar age.

Fossils.—The fossils hitherto discovered in the Talchir rocks are few in number. Animal relics, with the exception of those in the Salt Range locality, comprise only the wing of a neuropterous insect, some annelid tracks and some doubtful three-toed foot-prints. Plant remains usually consist of indistinct carbonaceous markings, coaly films, stem impressions and a few seed vessels, but the following is a list of what have so far been collected, most of the specimens coming from the Karanpura area.[1]

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[1] E. R. Gee. *Mem.*, LXI, 37 (1931).

[2] C. S. Fox. *Mem.*, LVI, 25 (1930). The grooved and striated condition of the surface of the Malani porphyries near Pokaran in Rajputana is attributed to wind action in spite of the fact that the locality is characterised by a boulder bed ; in any case the bed of boulders, none of which is recorded as striated, is believed to be of pre-Cambrian or very early Palæozoic age, and therefore much older than the Talchir.

[3] *Mem.*, XIII, 16 (1877).

[4] R. D. Oldham. *Rec.*, XXII, 55 (1889).

Equisetales—
  Schizoneura cf. *gondwanensis* Feistm.

Pteridospermæ and Filicales—
  Gangamopteris cyclopteroides Feistm.,
  ,, *angustifolia* McCoy.,
  Glossopteris indica Schimp.[2]

Cordaitales—
  Cordaites (*Noeggerathiopsis*) *hislopi* Bunb.

Schizoneura, one of the Equisetales, is found also in the Damuda and the Panchet series. The genus *Gangamopteris* is confined to the Palæozoic, and in India was most abundant in Talchir and Karharbari times; it occurs in formations homotaxial with the Talchir and Damuda in South America, South Africa and Australia, as well as in the Permian of Russia. In addition to the normal species, three varieties of *Gangamopteris cyclopteroides* have been described from the Talchir and Karharbari rocks—*subauriculata*, *areolata* and *attenuata*—but they are too ill-defined to carry any differential significance. The vegetable remains of the Talchirs have hitherto been found only in the higher beds of the stage, and even here they are of very rare occurrence; in the lower shales, which seem admirably suited for the preservation of vegetable impressions, there is a notable absence of such.

Mode of accumulation.—With regard to the mode of accumulation of the Talchirs, there is ample evidence that under the conditions that prevailed during the earlier part of the epoch, a large proportion of the Peninsula was covered by an extensive mantle of ice which, there is reason to conclude, was localised along the lines of the present Gondwana valley-outcrops, though exceeding them greatly in width. From their snowy gathering-grounds, the ice-sheets presumably became separated from each other lower down by broad rocky divides of land to form separate glaciers; from these divides were derived the boulders of the Talchir moraines. These large masses of ice, by their slow, polishing movement, would have planed down protuberances and filled up hollows with débris. The extreme fineness and the remarkably constant character of most of this débris are thus accounted for, since it would have consisted of rock powdered and re-powdered to an excessive degree by the incessant grinding caused by the flow of the glaciers. Most of the débris would be of local origin, but some of it would have been brought from distant regions and, if coarse enough, would betray its derivation by its lithology. The melting and retreat of the ice would have laid bare a bleak countryside consisting of the persistent divides and, between them, the broad ice-scoured valleys, their original drainage lines complicated by the irregular covering of moraine and silt. Upon the uneven bottom of the broad valleys, marshes and lakes would have formed readily and transiently, streams would have taken the place of the glaciers, and sedimentation would have commenced, accompanied by a certain amount of resorting of the moraine, especially towards the lower end of the valley.

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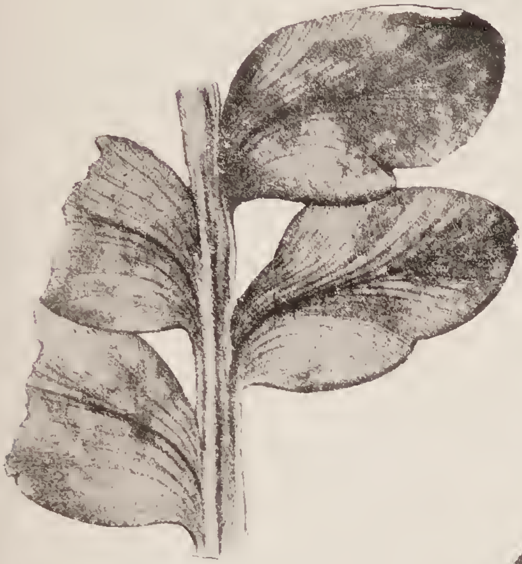
[1] O. Feistmantel. *Pal. Ind.*, Ser., XII, Vol. III, 6-7 (1870-81).

[2] The so-called *Glossopteris communis* Feistm. (*vide Pal. Ind.*, New Ser., Vol. II, Mem. 1, p. 3 (1902)).



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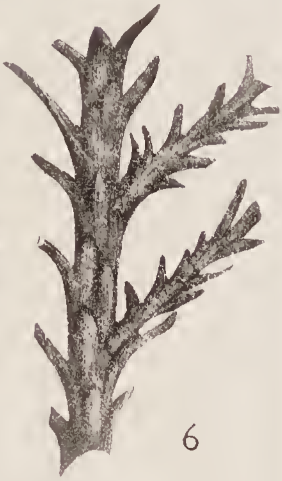

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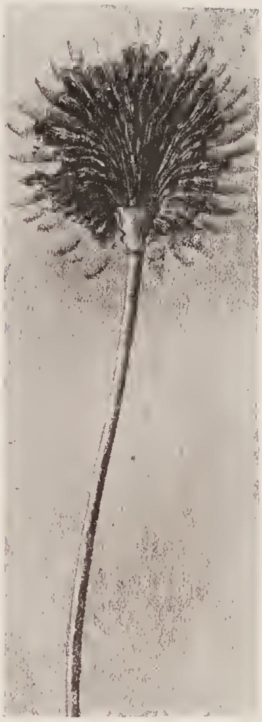

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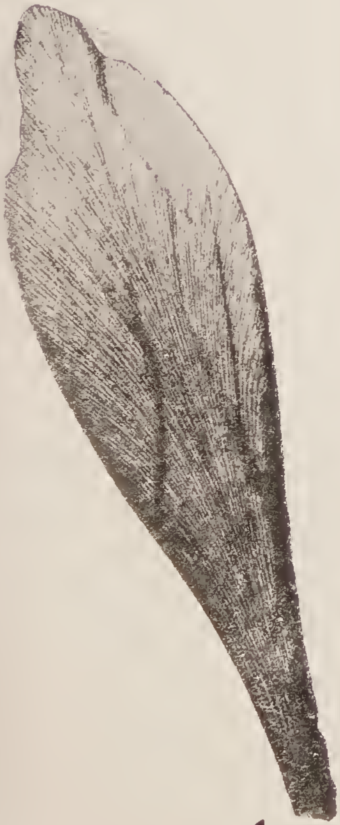

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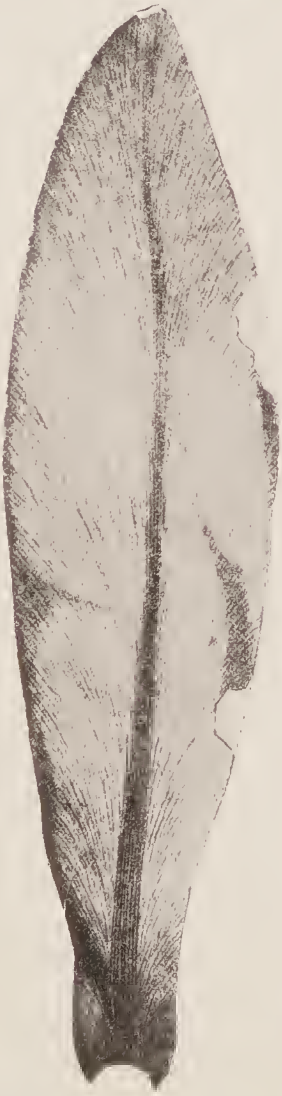

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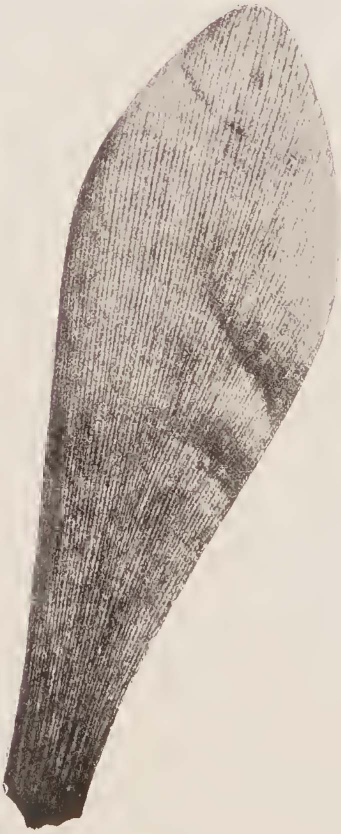

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TALCHIR AND KARHARBARI FLORAE.

1. *Gangamopteris cyclopteroides,* var. *major* Feistm. 2. *Gangamopteris cyclopteroides* Feistm. 3. *Cordaites (Noeggerathiopsis) hislopi* (Bunb). 4. *Ottokaria bengalensis* (Zeill). 5. *Gondwanidium validum* (Feistm). 6. *Buriadia sewardi* Sahni.

G. S. I., Calcutta.

The evidence with regard to the direction in which the ice moved is more or less conclusive in the case of the Damodar valley, where it seems to have flowed from west to east. In the extreme west or Karanpura field, the Talchir sediments, which are of no great thickness, are characterised by great irregularity, lenticularity and a lack of definite stratification, and are much coarser on the whole than they are farther east; conglomerates are more frequent, the sandstones are described as often pebbly and sometimes include lenticles of conglomerate, while others are highly current-bedded. The matrix in which lie the boulders—which incidentally do not appear to have attained the size they sometimes did further down the valley, though in many cases showing glacial striæ—is sandy and the Boulder Bed itself is associated with a roughly-bedded sandy conglomerate.[1] The shale, although constituting the bulk of the Talchir material, is more or less sandy. In the next field further down the valley, *i.e.*, Bokaro, much of the Talchir stage consists of fine-grained sandstones, some of them with conglomerate bands but most of them with intercalated beds of needle-shale; one of the boulders in the basal bed measured 42 feet in circumference.[2] Further down still, in Jharia, the Boulder Bed is only some 50 feet thick, and the remaining 750 feet are described as " earthy or argillaceous " in character. Many of the boulders in the Boulder Bed show scratching, but the bed in places exhibits signs of water-sorting; some of the boulders are composed of a quartzite which resembles closely certain Vindhyan rocks of Central India and Mirzapur, and are, in that case more likely to have been transported from west to east than in the opposite direction. Finally, in Raniganj, according to Gee, evidence of direct, undisturbed glacial action is wanting, if we except the polished floor at Podadih; the basal bed is of no great thickness compared with more westerly areas, and the boulders have lost their striæ.

In the cases of the Mahanadi and Godavari, the evidence is less clear. In the first place, we might expect that, if the glaciers along the Damodar valley flowed from west to east, the chances are that those of the Mahanadi originated in a gathering-ground adjoining or not far from that of the Damodar ice, and moved southeastwards; this supposition, however, has to be reconciled with the fact that at the northwestern end of the prolonged line of the Mahanadi exposures, in southern Rewah, beds with marine fossils overlie the Talchir sediments and are followed immediately by beds containing the remains of terrestrial plants proving that this area was in close proximity to a northern coast-line in Talchir times. In the case of the Godavari line of basins, we know that fragments of Vindhyan sandstone and limestone have been recognised in the Talchirs of Kamthi and would seem, therefore, to have been derived from country to the north of northwest. Since the Kamthi outcrop is in a line with the Godavari exposures and probably continuous therewith beneath the Trap, the chances again seem to be in favour of a movement of the ice from northwest to southeast towards a region which is known to have been covered by the sea a long time later.

A sequence similar to that in southern Rewah is seen in the Salt Range, where, in fact, the Talchir Boulder Bed itself contains marine fossils; this is a clear indication that another of the great Talchir ice-channels had a northerly direction, a suggestion supported by the presence in the Salt Range Boulder Bed of pebbles derived from the Malani rhyolites and the Rajputana granites. Of the neighbourhood of a coast-line there is evidence also in Kashmir.

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[1] A. Jowett. *Mem*., LII, 4 (1925).

[2] T. W. H. Hughes, *Mem.*, VI, 45 (1867).

The areas mentioned in the preceding paragraph are the only ones in which we can be quite certain that marine or coastal conditions prevailed in Talchir times. Elsewhere, where marine fossils are absent but where the Talchir boulders have every appearance of having been dropped by floating ice on to a bottom of fine mud, it is not impossible that such disburdening took place in large glacial lakes or in narrow estuaries. In spite of the infrequency of glacial pavements, the absence of marine fossils from the bulk of the Talchir and immediately superjacent deposits makes it probable that most of the ice of the epoch was land ice, and that all but a small proportion of the Indian Talchir sediments were accumulated under sub-aerial conditions. After the period of glaciation had passed away, a land flora soon began to take possession of the terrain from which the ice had retreated.

The Talchirs of the Salt Range and of the Himalaya have already been described (pp. 746), and an account of their occurrence in western Rajputana will be found on page 1072. Respecting the precise age of the peculiar and restricted marine fauna found in the Boulder Bed of the Salt Range and at corresponding horizons in Australia and elsewhere, opinions differ. Some would assign it to the Lower Permian, one authority persists in regarding it as Middle Permian, while others prefer to look upon it as Upper Carboniferous, a view which has been generally supported by the Geological Survey of India.

II.—DAMUDA SERIES

Definition and thickness.—The Talchir series or stage is succeeded by the Damuda series, which was first investigated in the coalfields of the Damodar valley, from the older spelling of which it is nâmed. If we include in this series the Karharbari beds, nearly all the coalfields of the Indian Peninsula owe their mineral wealth to the presence of the Damuda formation, the most important part of the Gondwana system. In its type areas, it has a total thickness of about 6,700 feet in the Raniganj field and about 5,900 feet in Jharia, decreasing gradually westwards in the Bokaro and Karanpura coalfields to less than half these figures ;[1] in the Satpura basin 7,000 feet or more are exposed. Summarising, it may be said that the Damuda at its maximum aggregate does not exceed 7,200 feet, of which nearly 360 feet consist of coal, something like 4,000 feet of sandstones, and the rest of shales and clays, carbonaceous or otherwise.

Fossils and correlation.—The Damuda series provides the main display of the *Glossopteris* flora, a flora which is essentially Palæozoic, including such genera as *Phyllotheca*, *Sphenophyllum*, *Glossopteris* and *Gangamopteris*. Correlating the basal Karharbari beds with the Artinskian, the Damuda series corresponds very closely with the whole of the European Permian, an equation supported by the undeniably Permian affinities of the only two animal fossils found definitely within the limits of the formation, *Gondwanosaurus* and *Archegosaurus*. The examination of the floras of the separate subdivisions of the Damuda series has shown that there are slight differences, but as nearly all the species of the Barakar stage, and without exception all the more abundant forms, are found also in the Raniganj stage, they have been united in a single list.[1]

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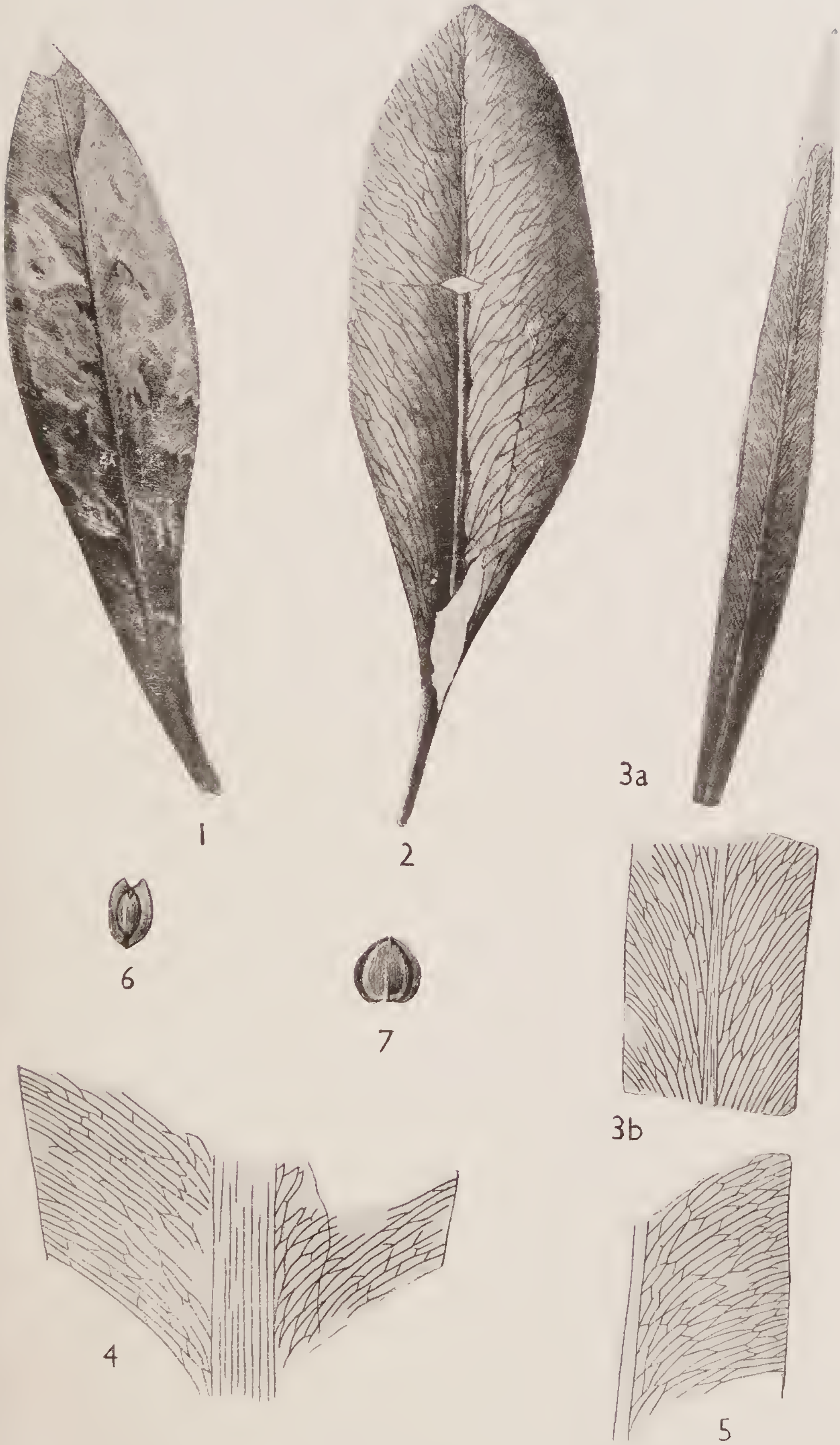
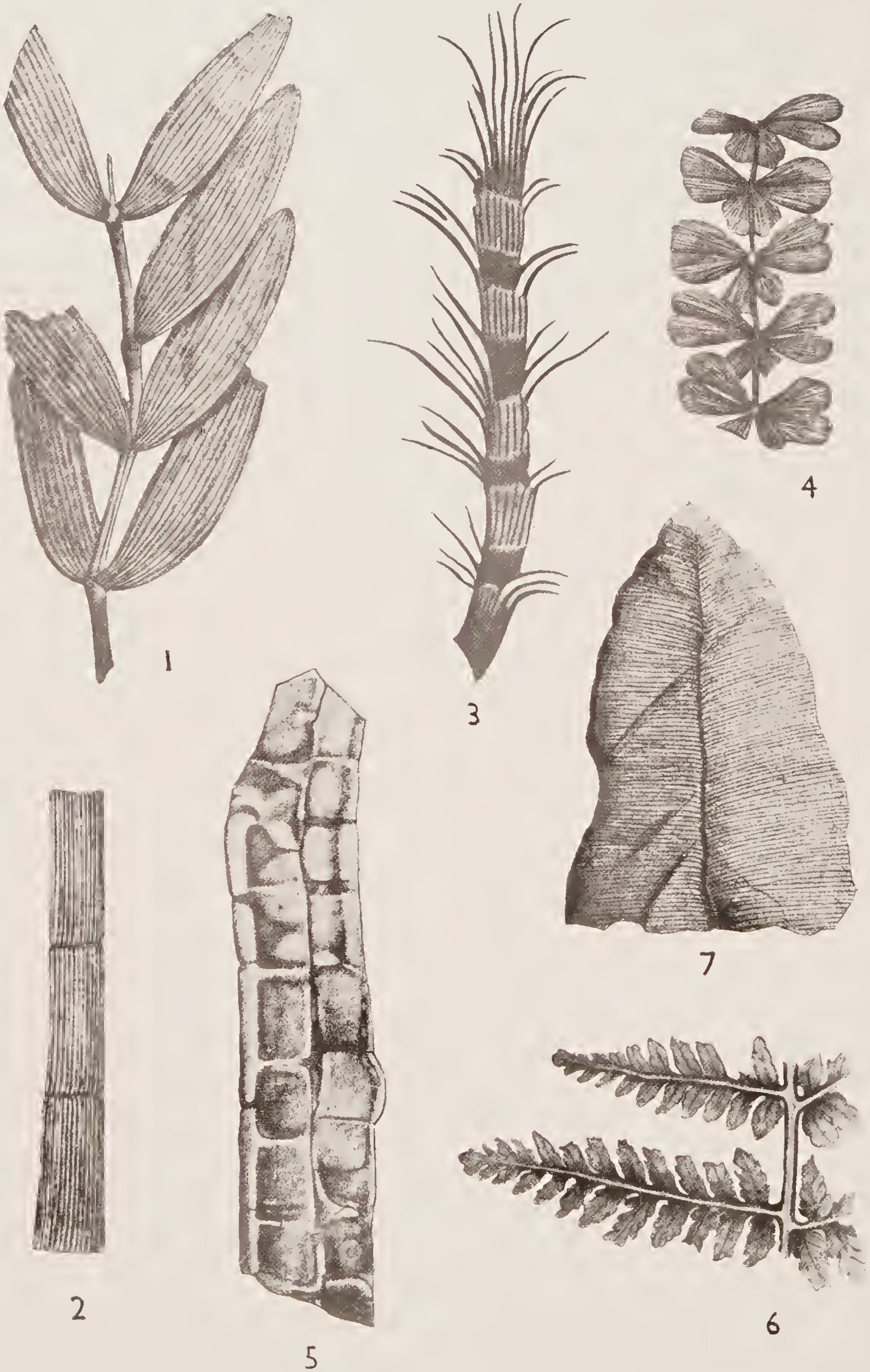
[1] C. S. Fox *Mem.*, LIX, 76 (1934).



DAMUDA FLORA (A).

1. *Glossopteris communis* Feistm. 2. *Glossopteris conspicua* Feistm. 3 (a,b). *Glossopteris angustifolia* Brong. 4. *Glossopteris indica* Schimp. 5. *Glossopteris browniana* Brong. 6. *Samaropsis raniganjensis* Sew & Sahni. 7. *Cordaicarpus* sp. cf. *C. cordai* Gein.

G. S. I., Calcutta.



DAMUDA FLORA (B).

1. *Schizoneura gondwanensis* Feistm. 2. *Stem* of *Schizoneura gondwanensis*. 3. *Phyllotheca indica* Bunb. 4. *Sphenophyllum speciosum* (Royle). 5. *Vertebraria indica* Royle. 6. *Sphenopteris polymorpha* Feistm. 7. *Taeniopteris danaeoides* (Royle).

G. S. I., Calcutta.

Lithology.—The Damuda strata include varieties of fresh-water sediments from coarse pebbly sandstones to fine shales, with fire-clays, coal seams and bands of more or less ferruginous material. Limestone is absent, but thin irregular and lenticular beds of siderite produce limonitic and hæmatitic iron-ores on the surface. The most persistent members of this series are the coal seams which are often traceable continuously for twenty miles or so from one end of a field to the other. Throughout the whole sequence there is evidence of sorting action. That the sediments were accumulated in wide river valleys or extensive lakes is borne out not only by the presence of coal, but by the frequent splitting of the seams when traced laterally, by the impressions of land plants, by the coarseness and the current-bedding of many of the sandstones, by the insensible passage of some of the coal seams into carbonaceous shale, and by the occurrence, rare though it is, of pebbles in the coal. A common sequence comprises a sandstone, often pebbly, overlain by shale or carbonaceous shale and this by a coal seam, followed by coarse sandstone forming the roof of the seam and starting a fresh cycle.

Damuda species.	Karhor-bari.	Barakar.	Ironstone shales.	Raniganj.	Newer beds.	Remarks.
Equisetales—						
Schizoneura gondwanensis Feistm.	..	..	..	..	..	Found also in S. Africa, S. Rhodesia, Brazil, New South Wales nd parts of the old continent of Angaraland. Some of the flat and broader stems referred by Feistmantel to *Schizoneura* are identical in appearance with stems described from India and elsewhere as species of *Phyllotheca*. (Seward. "Fossil Plants". vol. I. 293).
,, *wardi* Zeill.	..	..	..	..	..	Karharbari beds of Giridih only.
Phyllotheca indica Bunb.	..	..	..	..	..	Probably identical with the Australian species *P. australis* Brongn. (See *Schizoneura*).
,, *griesbachi* Zeill.	..	×	..	..	..	Barakar beds of Southern Rewah (*Pal. Ind.*, New Ser., Vol. II. 30); found also in Brazil.
,, *robusta* Feistm.	..	..	..	..	..	....
Actinopteris bengalensis Feistm.	..	..	..	×	..	Probably belonging to a new genus of Equisetales.
Sphenophyllales—						
Sphenophyllum (Trizygia) speciosum Royle.	..	..	..	..	..	Probably a climbing plant; found also in Queensland.
Lycopodiales—						
Bothrodendron ? sp.	..	..	×	..	..	....
Filicales—						
Cyathea cf. *tchihatcheffi* Feistm.	..	..	..	..	..	At first equated with *Sphenopteris polymorpha* Feistm., of which it may be a variety.
Cladophlebis roylei Arb.	..	..	..	..	..	Found also in Queensland.

Pecopteris phlegopteroides (Feistm.)	..	..	..	×	..	A very large species, the length of frond being probably 2½ feet.
Pteridospermae, Filicales et Plantae incertae sedis—						
Glossopteris indica Schimp.	×	×	×	×	×	Formerly "*G. browniana*, var. *indica*" includes *G. communis* Feistm. A frond of *Vertebraria indica.* Found also in the Antarctic, Argentina, the Felhland Islands, Brazil, S. Africa, Queensland, New South Wales, Tasmania, W. Australia and Tonkin.
,, *stricta* Bunb.	..	..	..	×	..	Another *Tæniopteris*-like form; found also in S. Africa.
,, *browniana* Brongn	..	×	..	×	..	Another frond of *Vertebraria.*; found also in the Falkland Islands, Brazil, S. Africa, E. Africa, Queensland, New South Wales, Tasmania and W. Australia.
,, *ampla* Dana	..	×	×	..	..	With this Arber includes "*G. cordata*"; found also in Brazil, S. Africa, Queensland, New South Wales, Tasmania, W. Australia and Antarctica.
,, *retifera* Feistm.	..	×	×	×	..	Includes Feistmantel's "*Sagenopteris polyphylla*"; found also in Argentina and S. Africa.
,, *conspiena* Feistm.	..	..	×	×	..	Resembles the preceding; recorded also in S. Africa.
,, *angustifolia* Brongn.	..	×	×	×	×	Sahni has shown this form to be distinct from *G. indica.* Seward has suggested its being a variety of *G. browniana.* It includes Feistmantel's "*Sagenopteris longifolia*". Found also in the Falkland Islands, S. Africa, E. Africa and W. Australia.
,, *formosa*, Feistm. and var. *major*.	..	..	..	×	..	Possibly belonging to the same plant as *G. retifera* or *G. conspicua.*
,, *tortuosa* Zeill.	..	..	..	×	..	Found also in Queensland.
,, *decipiens* Feistm.	×	..	..	..	..	A transitional type between *Gangamopteris* and *Glossopteris.* Found also in New South Wales.
,, *divergene* Feistm.	..	..	..	..	..	....

Damuda species.	Karhar-bari.	Barakar.	Ironstones shales.	Raniganj.	Newer beds.	REMARKS.
Glossopteris congicaulis Feistm.	..	..	..	..		......
Glossopteris damudica Feistm.	×	×	×	×	×	Probably includes *G. musæfolia* Bunb. *G. damudica* is considered by Seward to be probably the equivalent of "*G. communis*" (="*G. browniana*, var. *indica*"), and by Arber to be that of *G. ampla*: judging from its range it seems more likely to be the former. Found also in the Falkland Islands.
Vertebraria indica Royle	×	×	..	×	?	Found also in S. Africa and Queensland.
Merianopteris major Feistm.	..	..	..	×	..	The rhizome of *Glossopteris browniana* and other species of *Glossopteris*. Found in the Aurunga coalfield in beds which may be Panchets or Mahadevas.
Gangamopteris angustifolia McCoy	×	..	..	..	..	Found also in Queensland, New South Wales, Victoria and Tasmania.
,, *cyclopteroides* Feistm.	×	×	×	×	..	To this plant also belong McCoy's *G. obliqua* from the Karharbari (found also in the Bacchus Marsh beds of Victoria and Feistmantel's *G. hughesi*). Found also in Argentina, the Falkland Islands, Brazil, S. Africa, Queensland, New South Wales, Victoria and Tasmania.
,, ,, *var. major* Feistm.	×	..	..	..	..	The other varieties, *subauriculata*, *areolata* and *attenuata*, all from the Karharbari stage, are not very distinct.
,, ,, *buriadica* Feistm.	×	..	..	..	..	....
,, *whittiana* Feistm.	..	..	..	×	..	....
Alethopteris [*Asplenium*] *whitbyensis* Heer.	..	..	..	?	×	Probably *Cladophlebis-denticulata* Brongn. It is doubtful whether this form occurs so early as the Raniganj stage.

Neuropteridium (*Gondwanidium*) *validum* Feistm.	×	..	..	..	..	Found also in Argentina and S. Africa; the equivalent of *N. plantianum* White from Brazil, and very close to *N. grandifolium* Schimp. and Mong. from the Trai of the Vosges.
Sphenopteris polymorpha (Feistm.)	..	×	..	×	..	....
,, (*Dicksonia*; *Dicksonites, hughesi* (Feistm.).	..	..	..	..	..	Nearly identical with the Australian form *Sphlobifera* (Arber).
Palæovittaria Hurzi (Feistm.)			..	..	..	....
Belemnopteris wood-masoniana Feistm.		..	..	×	.	Found in the Trias of Ton Kin. In all probability a *Glossopteris* frond, since it has been found attached to a *Vertebraria stem.* (*Proc. 13th Ind. Sci. Congress*, 1926, p. 245.)
Dictyopteridium sporiferum Feistm.	..	×	..	×	..	A specimen from south Rewah (Raniganj series) shows resemblances to *Rhizomopsis*, a member of the *Gigantopteris* flora of China (H. S. Rao. *Rec.*, LXIX, 171).
Buriadia heterophylla (Feistm.).	×	..	..		..	....
,, *sewardi* Sahni	×	..	..	..	..	Specimens referred originally to *Voltzia heterophylla* Brongn. and *Alberta* ? sp., Possibly a cycad or conifer. Found also in the Argentine.
Barakaria (*Cyclopitys*) *dichotoma* (Feistm.).	..	×	..	..	..	....
Cordaitales—						
Cordaites (*Noeggerathiopsis*) *hislopi* Bunb.	×	×	×	×	..	....
Cordaites var. *subrhomboidalis*	×	..	..	..	..	....
Cordaites (*Noeggerathiopsis . Glossozamites*) *stoliczkanus* (Feistm.).	×	..	..	..	..	cf. *C. Hislopi.*
Euryphyllum whittianum (Feistm.)	×	..	..	..	..	cf. *C. Hislopi.* Found also in Argentine.
Cordaicarpus indicus (Zeill.)	×	..	..	..	..	Called originally *Cardiocarpus*, a name now restricted to seeds in which anatomical features are preserved. (*Pal. Ind.*, New. Ser., Vol. VII, Mem. I, II.)
,, cf. *cordai* Gein.	..	×	..	..	..	....

	Karharbari.	Barakar.	Ironstone shales.	Raniganj.	Newer beds.	REMARKS.
Arberia indica White.	×	..	..	..	..	....
Samaropsis raniganjensis Sew. and Sahni	×	..	..	×	..	....
,, (*Carpolithes, milleri* (Feistm.)	×	..	..	..	..	....
,, cf. *parvula*	×	×	..	×	×	....
Dadoxylon indicum Hold.	?	×	..	..	..	(R. Holden. *Annals of Botany*, XXXI, 315 (1917).)
,, *bengalense* Hold.	?	..	..	..	..	Ditto.
,, *za esskyi* Sahni	..	..	..	×	..	....
,, *parbeliense* Rao	..	..	..	×	..	(*Rec.*, LXIX, 174.)
Cycadophyta—						
Taeniopteris (*Macrotaeniopteris*) *danaeoides* (Royle).	..	×	×	×	..	....
,, (*Macrotaeniopteris*) *feddeni* (Feistm.)	..	×	..	×	..	....
,, (*Angiopteridium*; *Stangerites*) cf. *macclellandi* (Morr.).	..	..	..	×	×	Raniganj stage, Kamthi stage and Upper Gondwanas.
Pseudoctenis (*Platypterygium*; *Pterophyllum*) *Anomozamites balli* (Feistm.)	..	×	..	..	..	....
Ottokaria bengalensis Zeill.	×	..	..	..	..	At first called "*Feistmantelia bengalensis*".
Rhipidopsis ginkgoides (Schmal)	..	×	..	..	..	Found also in Argentine.
,, *densinervis* Feistm.	..	..	..	×	..	Found also in Argentine.
Coniferales—						
Moranocladus (*Araucarites*) *oldhami* ? (Zeill,)	?	..	..	..	..	Horizon somewhat doubtful (*Pal. Ind.*, New. Ser., Vol. XI, Mem. I, 7). At one time named *Morania oldhami*.

Foltzia ? heterophylla Brongn.	..	..	..	×	..	A cone scale. Found also in Antarctica and in parts of the old Angara continent.
2. Among rejected determinations are the following :—						
Sagenopteris cf. *rhoifolia* Presl.	..	..	..	..	..	Raniganj stage. May be a scale frond of *Glossopteris*. *S. rhoifolia* is found in the Jurassic (including the Rhaetic) of Queensland.
Glossopteris intermittens Feistm.	..	..	..	..	..	Barakar stage. A poorly-preserved, *Tæniopteris*-like form, perhaps referable to some other species.
,, *leptoneura* Bunb	..	..	..	..	..	Raniganj stage. Scarcely distinguishable from *G. angustifolia* of which it may be a variety.
,, *orbicularis* Feistm.	..	..	..	..	..	Raniganj stage. Perhaps an immature stage of some other species, and possibly the equivalent of *G. spatulato-cordata* from New South Wales and Tasmania.
,, *Sagenopteris staliczkana* Feistm.	..	..	..	..	..	Karharbari stage. Fronds undoubtedly those of *Glossopteris*, very possibly of *G. retifera* or *G. decipiens*; to the same plant probably belong "*Sagenopteris polyphylla* Feistm." and "*Glossopteris acaulis* McClell.
,, *tæniodes* Feistm.	..	..	..	..	..	Karharbari stage. Imperfect; probably belonging to *G. angustifolia*.
,, *ingens* Feistm.	..	..	..	..	..	Barakar stage. Too poorly preserved for even generic determination.
Gangamopteris cf. *spatulata*	..	..	..	..	..	Karharbari stage. Possibly belonging to *G. cyclopteroides*.
,, *anthrophyloides* Feistm.	..	..	..	..	..	Too imperfect for specific differentiation.
Sphenopteris [*Pecopteris*] *affinis* McClell.	..	..	..	..	..	Raniganj stage. Probably identical with *S. polymorpha*.
Tæniopteris (*Angiopteridium* : *Stangerites*) *infarcta* (Feistm.).	..	..	..	..	..	Barakar stage. Probably indentical with *T. maclellandi* (Morr.).
Pterophyllum (*Zamia*) *burnwanense* Feistm.	..	..	..	..	..	Raniganj stage. Perhaps a torn frond of *Tæniopteris*.

There is no widespread hiatus throughout this thick series of beds, passage from one stage to another is frequently transitional, and none but slight unconformities can be detected. As already indicated, there is often a perceptible discordance and overlap between the base of the Damudas and the Talchirs but even this is sometimes absent ; in the Satpura region, in the Korea State of the Central Provinces, and in the extreme western part of the Raniganj field, for instance, the passage from one series to the other appears to be transitional.[1]

Mode of deposition.—After the retreat of the Talchir ice, the Gondwana areas of deposition became alternatively a chain of stream-connected lakes and marshes in the comparatively still waters of which vegetable debris and carbonaceous shale accumulated, or broad river valleys from side to side of which wandered rivers depositing the coarser silts, sandstones and gravels which formed the rest of the Gondwana system. As the lakes became silted up, their place was taken by sluggish reaches of the meandering river, until some change in conditions—perhaps a land-slip, or a renewal of local subsidence due to faulting—brought about a re-formation of the lakes. Such a cycle seems to have been repeated time after time.

Subdivision.—The Damuda series has in the past been divided into three stages which from below upwards were : the Barakar, the Ironstone Shales and the Raniganj. The Karharbari group, which was regarded as an upper member of the Talchir series, is but an early phase of the Barakar and scarcely merits separation therefrom. Since it has received separate attention in the past and its flora differentiated, it will be separately described where distinguishable ; it has, at any rate, as much individuality as some of the other stages in a necessarily artificial classification. Objection has also been advanced against the establishment of the Ironstone Shales but here, again, the group has been mapped separately and its small flora individualised ; as delimited by Blanford, it is retained until the question of its occurrence, boundaries and fossils in the three separate areas of Raniganj, Bokaro and Karanpura has been more thoroughly investigated. In the Jharia and Raniganj coalfields, the three Damuda stages have been further sub-divided and tentatively correlated as follows :—

	Raniganj coalfield.	*Jharia coalfield.*
Raniganj stage	Kumarpur sandstones.	Lohpiti sandstones.
	Nituria coal measures.	Telmucha coal measures.
	Hijuli sandstones.	Jamdiha sandstones.
	Sitarampur coal measures.	Murulidih coal measures.
	Ethora sandstones.	Mahuda sandstones.
Ironstone Shales (*after* Blanford).	Kulti Ironstone Shales.	Hariharpur carbonaceous shales.
	Begunia sandstones.	Petia sandstones.
	Begunia shales.	Shibbabudih shales.
Barakar stage	Begunia coal seam.	Seams of Jorapokar, etc.
	Laikdih seam, etc.	Seams of Jagta, etc.
	Damagaria seam.	Seams of Nardkarki, etc.
(Kerharbari)	......	? Seams of Matiagaria, etc.[2]

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[1] L. L. Fermor. *Mem.*, XLI. 168 (1913) ; *Rec.*, LIX. 88 (1926).

[2] C. S. Fox suggests that the basal measures of the Jharia coalfield with their curious dull coals may possibly be the equivalents of the Karharbari seams of Giridih.

The lower boundary of the Ironstone Shales was drawn by Blanford at the base of the Begunia shales but there is no unconformity at this horizon and the overlying Begunia sandstone is of the typical coarse Barakar aspect and current-bedded on an unusually coarse scale.[1] For these reasons, Gee has preferred to draw the boundary at the top of the Begunia sandstones ; the older method of subdivision has, however, been retained in the present work until the floras of the subdivisions can be adjusted—if adjustment should prove necessary—to the proposed modification of the boundaries.

The lowest or Karharbari sub-stage or phase is found in the Giridih of Karharbari coalfield of the Hazaribagh district, and less certainly in other parts of Bihar, in the Son valley, and in the Satpura region. The Barakar has as wide an extent in the Peninsula as the Talchir and is recognisable not only in the Damodar valley but in the Rajmahal area, in Birbhum, Deogarh and Giridih, in the Son, Mahanadi and Brahmani valleys, in the Satpura region, and in the Godavari valley ; it is not seen south of the Godavari and, with other members of the Lower division, is absent in the Gondwana exposures of Cutch and Kathiawar. The Ironstone Shales of the Raniganj coalfield have been identified in Karanpura and Bokaro, and are thought to be represented by certain sub-stages in Jharia. The Raniganj stage of the Damodar valley is represented in the Son, Mahanadi and Brahmani valleys by the Pali and Hingir stages, in the Satpura region by the Bijori stage, and in the Godavari valley by the coal-less Kamthi stage. The mineral characters and geological relations of the different subdivisions of the Damudas will be described separately, but the following remarks on the coal seams and their associations apply to the series as a whole.

Coal seams of the Damuda series.—The Damuda coals, with the exceptian of those in the Karharbari stage and those of the Matiagaria and Muraidih seams in the lower Barakars of Jharia[2], all agree in having a peculiar laminated appearance, due to alternating layers of bright (vitrain) and dull (durain) coal. The laminae of vitrain, a substance which, according to Fox, appears to have originated from the cortical tissues of Gondwana trees and plants and is the more purely bituminous part of the coal, are usually lenticular and may either disappear in the space of a few inches or are traceable for several feet. The durain, which is probably a colloidal mixture of carbonaceous and clayey materials, grades insensibly into carbonaceous shale. Speaking of the coals of Karanpura, Jowett finds no essential difference in composition between the ash of a coal and its associated shale.[3] Fusain, another variety of coal substance, derived from woody tissue, is very common in all Lower Gondwana coals.[4]

The lower the moisture contents of Gondwana coals, the greater their caking powers ; according to Fox, 5 per cent. of moisture diminishes the caking qualities of a coal more than what 20 per cent. of the impurities generally termed ash can do. In the Damuda seams of Jharia, western Raniganj and Giridih, the moisture is seldom more than 1·5 per cent. in the lower, or more than 3 per cent. in the upper, seams ; in eastern Raniganj, Talcher, south Rewah and Rajmahal, on the other hand, most of the coal contains at least 5 per cent. and not uncommonly more than 10 per cent. of moisture. Assays of Jharia coal quoted by Fox show that, in support of Hilt's Law, the proportions of volatile matter and of moisture appeer to decrease with depth.[1] The percentage of phosphorus is unusually high, averageing 0·45 in thirty-one of the Raniganj coals; some of this ingredient was no doubt original in the plant substance and derived from the surrounding metamorphic rocks which are also phosphatic, but Fox is of opinion that the excess of phosphorus found in the coal immediately bordering igneous intrusions of highly phosphatic peridotite originated from the decomposition of the latter caused by percolating waters. The coal of many of the Jharia seams, especially those in the two uppermost Barakar sub-stages, yields a good metallurgical coke, a factor which has done much to make Jharia the most important Indian coalfield. No true anthracite is known in India though, as an outcome of tectonic squeezing, some of the crushed coal in the Lower Gondwana seams of the Darjeeling Himalaya shows an analysis approximating that of an anthracite; a semi-anthracite occurs sometimes at the base of the Barakars.

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[1] C. S. Fox. *Rec.*, LX, 363 (1928).

[2] These, however, differ in analysis from the Karharbari coal.

[3] *Mem.*, LII, 139 (1925).

[4] C .S. Fox. *Mem.*, LVII, 113-114, 116 (1931).

There is a general tendency to variation not only in thickness but also in quality of a seam within short distances. In one of the Karanpura seams, for instance, the ash percentage falls from 33·2 to 15·4 in a vertical distance of four feet, rises in the next foot to 23·8, sinks in the next five feet to 10·5, and so on. Some of the Barakar coal exhibits a peculiar spheroidal structure, and round balls of various sizes, up to more than a foot in diameter, break away from the mass when the coal is mined. Methane and carbon dioxide—"firedamp" and "chokedamp"—have been met with in Indian mines and appear to be held in fissures and inter-stratal spaces under pressure; these gases ədɐɔsə either as "blowers", continuing for days or even weeks, or in the from of a slow presistent discharge.

Gondwana coal is made up of the débris—largely of a woody nature—of plants which, when sufficiently intact, can be identified as terrestrial forms; this, incidentally, applies not only to the *Glossopteris* flora of the Damuda series but also to the *Ptilophyllum* flora of the Upper Gondwanas. Plant structures can frequently be discerned in sections of the coal. Annual rings of growth have been made out in many Gondwana woods, and bodies like microspores in some cases identified. In one of the Karharbari coals, Mr. A. K. Banerji found spheroidal alveolated bodies very similar to the *Sclerotites brandonianus* of Jeffrey and Chrysler, which is thought to be the sclerotium stage of a fungus and therefore an indication of a more or less moist climate.[2]

With regard to the mode of accumulation, evidence on the whole is in favour of the "drift" theory and, according to Sir Cyril Fox, comparatively deep-water conditions are indicated in spite of the pebbly nature of the sandstone so often found lying upon the coal seams. There is very little sign of inter-depositional erosion; although there is occasional local overlap above a coal seam, no instance is known in India of a coal seam lying unconformably on the beds below. That the coal substance, or at any rate the fragmentary vegetation which produced it, was transported from the vast forests of the catchment area and did not originate *in situ* receives some measure of support from the following considerations. In the first, though of rare occurrence, pebbles and concretions consisting of a nucleus of coal coated with successive layers of calcite have been recorded in some of the coal seams.[1] Secondly, some of the seams split frequently into several thin seams separated from each other by wedge-shaped intercalations of shale and sandstone varying considerably in thickness. Several of the seams attain considerable thickness but most of them have interstratified bands or lenticular layers of carbonaceous shale or even of sandstone. Some of the seams pass laterally into carbonaceous shale. The banding, which is characteristic of many of the seams, is, in fact, often very persistent and suggests allochthonous origin ; as Gee notes, the bands evidently represent a mixture of fine inorganic material and the mother substance of coal, brought down and sorted by the action of currents, evidence of which is seen in the current-bedding of associated sediments.[2] Thirdly, although the seam floor, which is typically a bed of carbonaceous shale and less frequently a sandstone, may be characterised by the presence of *Vertebraria* roots, plant fronds (*Glossopteris*, *Pecopteris*, etc.) and fruits (*Samaropsis*) ; such remains are indiscriminately distributed, the tougher structures lying irregularly across the lamination of the shale. The parting between the two strata is clean and no plant structures are seen to continue up from the floor into the seam ; there are no erect tree stems, and none of those found in the coal is attached to roots in the floor below. Basal fire-clays do occasionally underlie the seams, but in the majority of cases are absent ; in any case, there is nothing to show that these underclays were at any time soils exposed to the sun and rain. Fourthly, in the roof, which may be composed of carbonaceous shale, grey shale, sandstone or even pebble beds, there are sometimes found flattened, branchless tree stems, perhaps ten or fifteen feet in length with the cortical sheath surviving as bright coal but the woody interior either perished or replaced by iron oxide or sideritic material frequently showing a woody structure.[3] Such trunks, some of them 12-18 inches across and 12-18 feet long are occasionally seen resting prone on the top of the coal, but never on the floor of the seam.

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[1] *Mem.*, LVII, 55 (1931).

[2] *Rec.*, LXVI. 341 (1932)

The almost complete absence of a fauna—of even a vertebrate fauna—in the coal measures is not easily understood, but Fox suggests that this is perhaps due to the hilly nature of the country supporting the forests which supplied the coal material ; whether the dearth of animal remains in the rocks is or is not attributable to the physiography of the Damuda country, the hilly character of the latter is confirmed by the coarseness of so many of the sediments.

In only one or two doubtful cases is there evidence of the partial erosion of seam known as a " washout ". Even when overlain by current-bedded sandstone and pebble beds, a Damuda coal seam shows no sign of erosion by the swift current which have left their mark in these roof deposits. Some measure of the comparative rapidity with which the consolidation of the coal seam took place is afforded by fragments of carbonaceous shale and coal in the Barakar sediments where, though rare, they are not entirely absent. Fossil tree trunks of coal and sideritic material, seen occasionally resting on the top of a seam, show no signs of having sunk at all into the surface of the latter, but have every appearance of having settled down on a firm unyielding bottom. This may be due in part to some residual buoyancy in the logs. Some of the pebbles, on the other hand, are seen to have indented the top of a seam, though they have not sunk appreciably into it, and in most cases Fox finds evidence of a complete conversion into coal before the deposition of overlying sediments. Nonetheless, most indications are in favour of the continual presence of water above the coal material during the deposition of the roof sediments and, as Fox notes, this seems more likely to have been the case in large river-fed lakes than in wide river valleys.

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[1] G. H. Tipper. *Rec.*, XL, 335 (1910).

[2] *Mem.*, LXI, 51 (1932).

[3] C. S. Fox. *Mem.*, LVII, 256 (1931).

Fossil logs.—Another occurrence which indicates that vegetable matter was brought from some distance, and therefore necessarily by rivers, is afforded by the presence of silicified tree trunks in some of the Damuda sandstones of both Raniganj and Jharia, especially in the zone of massive grey sandstones near the top of the Raniganj coal measures. These trunks are found lying prone, their woody tissue replaced by opaline silica, their small branches missing, and usually with no bark. Two such specimens, obviously drifted logs, were discovered a little west of Asansol. One of them, before excavation, had a length of 93 feet, tapering from a diameter of 2 feet, 7 inches, to one of 1 foot, 2 inches; two-thirds of the way up the trunk bifurcates, one of the branches being truncated, the other persisting. Seventy feet of this specimen are exhibited in the Indian Museum in Calcutta. Dr. B. Sahni identifies it as a species of *Dadoxylon*, a genus of the Cordaitales group of Palæozoic gymnosperms.[1] The softer tissues were evidently removed during transport and there remains only the woody interior, in which well-defined rings of growth bear witness to sharply-marked seasons of the year. A better preserved specimen, also from the topmost Raniganj horizon (Kumarpur sandstone) near Asansol shows pith and primary wood as well as secondary wood and has been named by Sahni *Dadoxylon zalesskyi*.[2] This specimen shows large numbers of branch scars, but no branches and no trace of bark or roots. Smaller pieces of fossil wood are numerous in this horizon, the bulk of the material apparently belonging to this species, and all specimens, large and small, show signs of decay before petrification set in. *Dadoxylon zalesskyi* seems to have flourished in great abundance in some part of the Damodar valley. Any one of the three species of *Dadoxylon* so far distinguished in the Damudas may well have borne the leaves known under the name of *Cordaites* (*Nœggerathiopsis*) *hislopi* Bunb. Some of these fossil drift logs are partly silicified and partly lignitised.[3]

As already remarked, the coal of the Gondwana fields is Permian in age and the Carboniferous coal of Europe is absent in India. Perhaps connected with this contrast in age is the fact that most Gondwana coal is somewhat inferior to the average European product, for the difference may not be entirely due to a larger admixture with extraneous clay but seems likely, in the opinion of Sir Cyril Fox, to have been influenced by a difference in the character of the floras which respectively gave rise to the coal in the following way. The greater the proportion of cortical tissue, the greater must have been the amount of vitrain produced and the higher the quality of the coal. Since the lycopods of the European Carboniferous are known to have had a larger proportion of cortex—three-fifths of the diameter in some *Lepidodendron* stems—than the later conifers or *Cordaites*, including such forms as the upper Palæozoic *Dadoxylon* or the Jurassic *Mesembrioxylon*, they must have produced a larger percentage of vitrain.[1]

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[1] *Rec.*, LVIII, 75-79 (1925).

[2] *Rec.*, LXVI, 414 (1932).

[3] C. S. Fox, *Mem.*, LVII, 65, 255 (1931).

Very rarely boulders may occur in a coal seam. There is nothing against their being derived boulders from the Talchir beds, and they may in that case represent redistributed moraine material. Whatever their primary derivation may have been, they may well owe their present position to the floods which are likely to have inundated from time to time the coal-producing marsh lands. As suggested by Sir Thomas Holland, they may have become entangled in floating tree-roots and thus transported ; their occurrence in other parts of the world in the vicinity of "wants" and "washouts" lends support to this suggestion.[2]

The coal industry of India.—Nearly all workable coal seams in India belong to the Lower Gondwana division ; occurrences of coal are known in the Upper Gondwanas but are seldom of economic importance. The first coal mine in India was sunk in the Raniganj area in 1774 during the Governorship of Warren Hastings, and was the result of enterprise on the part of the Hon'ble East India Company. Production in India has been more or less sustained since the year 1815, the highest output occurring in 1938 when 28,342,906 tons were raised. A little over ninety-eight per cent. of this came from the Lower Gondwana, and the remainder from Tertiary rocks. Nearly the whole of the coal raised is consumed within the country, much of it by the railways. Raniganj was superseded by Jharia as the most important producer in 1905. A recent estimate of the reserves of good quality Gondwana coal within 2,000 feet of the surface in India amounts to some 5,000 million tons, made up of 1,500 million tons of coking coal and about 3,500 million tons of the non-coking variety ; the total reserves of both first class and second class coal within the same depth are of the order of 40,000 million tons.[3]

The total thickness of coal in the Jharia field probably exceeds 200 feet, made up of some 30 seams—some of which, however, are duplications due to splitting—and only twelve are workable. Some of the individual beds of Damuda coal are of immense thickness, single seams, with shale partings included, amounting to as much as 100 feet in the Raniganj and Karanpura fields, to over 70 feet in the Singareni area, and to more than 60 feet in the Telwasa field of the Wardha valley. In the Bokaro coalfield there are three thick seams, one of them 100 feet (swelling in one place to 125 feet), another 40 feet and a third 80 feet. In the Korba field, two thick seams, one of them 80-100 feet thick, appear to unite to produce a single seam of 150 feet, though most of the coal is of poor quality and shale partings are frequent.

In nearly all Gondwana coalfields, the Barakar is the most important coal-bearing stage ; in the Raniganj field, it is the Raniganj stage which yields the bulk of the coal. The Barakar seams show greater lateral variation than do those in the Raniganj stage. Coals from the Raniganj stage are richer in moisture and in volatiles than are those from the Barakar, and many of them are consequently good gas coals; the coke they yield is, in most cases, too soft and porous for metallurgical purposes. In the case of the two principal coalfields of the Damodar valley, the Barakar stage is seen to diminish in thickness from Jharia eastwards to Raniganj, and the Raniganj stage to increase in thickness in the same direction. There is little doubt that the Raniganj field with its capping of Tertiary Durgapur beds extends eastwards under the Ganges alluvium, and it is not unlikely that unexplored coalfields lie hidden beneath the same extensive covering of Tertiary and Recent deposits in the provinces of Bengal and Bihar. Owing to their softness, coal outcrops are very apt to be concealed beneath surface deposits and for that reason are easily missed; the best sections are found in stream-courses.

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[1] C. S. Fox, *Mem.*, LVII, 215 (1931).

[2] *Trans. Min. Geol. Inst. Ind.*, I, 143 (1907.)

[3] J. Coggin Brown, "India's Mineral Wealth", p. 12 (1936).

Burnt outcrops.—A characteristic phenomenon in the Damodar valley coalfields is that of burnt outcrops, caused presumably by spontaneous combustion, some of them of comparatively recent date, others of considerable antiquity. These outcrops of hard burnt shales, baked sandstones and confused beds, showing evidence of actual fusion by the heat of the burning seam, are more resistant to erosion and remain as outlying ridges, witnessing to the former wider extent of Damuda outcrops. So similar are some of these fused products to normal igneous rocks that they have been mistaken for remnants of andesitic lava.[1] The soil in the neighbourhood of burnt outcrops is said to be richer than it is elsewhere.

(a) KARHARBARI STAGE.

Classificatory position.—The coal-bearing rocks of the Karharbari or Giridih coalfield were, in the last edition of this Manual, guardedly assigned to a place within the Talchir series but, in view of a recent discovery in south Rewah of a band containing marine fossils, lying below what are regarded as the Karbarbari coal measures and unconformably upon the Talchirs, the Karharbari substage has with good reason been restored by Fox to the Damuda series, where it was first placed by Mr. T. W. Hughes. The latter authority found it impossible in the south Rewah basin to separate it from the Barakar or lowest stage of the Damuda, and this has since been the experience in other fields. From a palæophytological point of view, the Karharbaris are somewhat closer to the Talchirs than they are to the Barakars, for practically all the few forms found in the Talchirs have been recognised in the Karharbaris—one of them, *Gangamopteris cyclopteroides*, being the commonest Kaharbari fossil—while, on the other hand, many of the common Damuda fossils are rare or wanting in the Karharbari and several remarkable species among the Karharbari assemblage have not been found in the other Damudas; nonetheless, the differences between the Karharbari and the other Damuda floras must not be exaggerated and typical Karharbari plants have been recorded in what appear to be the basal Barakar rocks in several of the coalfields. As a basal phase of the Barakar stage, the Karharbari would naturally exhibit a flora intermediate in affinity between that of the Talchir stage and the flora of younger Barakar horizons. The Karharbari coal and that of higher Damudas show structural differences, but Fox has shown that these are seen only when the *lower* Karharbari seam is compared with the *upper* Barakar seams, and that, in the Jharia field, for example, there is little difference between the lower Karharbari and the lower Barakar coal. In its peculiarly high quality, the coal of the Karharbari stage in Giridih—in both lower and upper seams—resembles that of the *higher* Barakar seams in the Jharia field.[1] Finally, there is in the Giridih coalfield a suspected unconformity and overlap between the Talchirs and the overlying Karharbari stage, corresponding to a marked difference in lithological character ; in contrast, there is a noticeable conformity between the Karharbaris and the overlying coal measures which possess all the characters of Barakar beds. In the west of the Karharbari basin, the Talchirs attain a thickness of about 500 or 600 feet whilst, within a distance of less than four miles to the east, the Karharbari beds rest directly upon the gneiss.

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[1] "Chirmiri Volcanic series". L. L. Fermor. *Mem.*, XLI, 158 (1914); L. L. Fermor. *Trans. Min. Geol. Inst. Ind.*, XII, 50 (1918).

Lithology.—Much of the material of the Karharbari sub-stage has been derived from the re-sorting of the Talchir deposits. The rocks consist almost solely of sandstones, grits and conglomerates, with seams of coal ; the very little shale which occurs is always associated with the coal seams. The sandstones are white, grey or brown in colour, felspathic, and often gritty and conglomeratic by reason of the large fragments of felspar and quartz. The grits and conglomerates, especially the coarser varieties, differ from those which make up so much of the Barakars, in that a large proportion of the fragments of felspar and quartz are angular or sub-angular instead of being particularly well rounded. In the Karanpura field, some of the fragments are of considerable size, and the material of the conglomerates can to a large extent be matched in the Talchir glacial beds ; in the same areas, layers of coal fragments are found among the sandstones and some of the latter rocks are highly current-bedded. The coal seams in the type area of Giridih are somewhat variable in thickness but undergo very little change in composition throughout the small area in which they are found. Unexpectedly, in view of its general high quality, the coal of the " lower " seam is of a dull variety which can, however, be matched, though not in quality, by coal in many of the Lower Barakar seams of Jharia.[2]

Distribution.—The thickness of the Karharbari beds in Giridih is said to be probably about 500 feet, but their upper limit is ill-defined. Outside Giridih, the Karharbari sub-stage is claimed to have been recognised in the basal Damudas of Deogarh, Karanpura, Aurunga, Hutar, Daltonganj, Umaria (Rewah), Pali (Johilla river), Mohpani (Narbada valley) and Shahpur (Betul), but in some of these areas the palæontological evidence is somewhat of a negative character ; in Hutar and Karanpura, there is said to be a lateral passage from Karharbari rocks to typical Barakar sediments with plant fossils. The sub-stage is not recognised in either Jharia, Raniganj or Bokaro, where it is probably represented by the lower portion of the beds mapped as Barakar, or by an addition to the unconformity sometimes seen above the Talchir stage. The same statement may well apply to other parts of India where the basal stage of the Damudas is usually referred to as the Barakar.

Plant remains.—The only fossils which have so far been found in the Karharbari beds, except those of the Umaria area, are plants, a list of which has already been given.

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[1] *Mem.*, LVIII, 128-132 (1931).

[2] C. S. Fox. *Mem.*, LIX, 67 (1934).

Umaria occurrence.—One of the most interesting facies of the Karharbari sub-stage, if correctly correlated as such, is seen in the Umaria coalfield of southern Rewah where, in a railway cutting some two miles northeast of Umaria railway station, beds of Karharbari or Lower Barakar age yielding marine fossils were discovered by Mr. K. P. Sinor. These beds, lenticular in occurrence, are described by Gee, under the designation of "Lower Barakars", as being of somewhat similar lithology to the yellow-brown, sandy clays of the uppermost Talchirs on which they rest with a slight but definite unconformity.[1] The fossils, determined for the most part by Dr. Cowper Reed, comprise the following[2] :—

Crinoidea.

Crinoidal stems and joints,

Calicular plates of *Dinocrinus* sp. or a genus related thereto.

Bryozoa.

Rhombopora sp.

Brachiopoda.

Productus umariensis Reed (the most abundant form, frequently forming the bulk of the rock ; closely allied to some of the types of *P. cora*.),

,, ,, , var. *spinifera* Reed,

,, *rewahensis* Reed,

,, ,, , var. *coroides* Reed,

Spirifer narsarhensis Reed (closely allied to *S.* (*Paeckelmannella*) *middlemissi* of the Fenestella beds of Kashmir),

,, ,, , var. *pauciplicata* Reed (also passage forms between this and the preceding),

Reticularia barakarensis Reed,

,, ,, , var. *subplicata* Reed,

Athyris (*Composita*) aff. *protea* Abich (closely resembling *A.* (*Composita*) *protea*, var. *alata* Abich, from the Kuling Shales of the Himalaya),

Orthotichia sp.

Lamellibranchiata.

Janeia aff. *biarmica* (de. Vern.).

Gastropoda.

Pleurotomaria umariensis Reed,

Some doubtful ostracods, perhaps assignable to *Jonesina*, *Cytherella* and *Palæocypris*.

The majority of the fossils are brachiopods and, in all cases where the material is sufficiently well preserved for specific identification, the species are new. The fauna, comprising only a few genera, thus has a striking individuality of its own, and is not particularly close to any previously described ; its nearest relations are partly with the Himalayan and Russian Permian, and partly with the Carboniferous of these and other regions. The presence of *Dinocrinus* would favour a Lower Permian age.[3] The marine invasion of the Peninsular region, to which this occurrence bears witness, was of a very transient nature and probably came from the north in Lower Permian times. These Karharbari beds pass up into strata of typical Barakar character, which overlap the marine fossil bands to rest probably upon the Talchirs, and consist mainly of massive grey sandstones, some of them felspathic, with intercalated coal seams and fire-clays ; four of the six coal seams are said to be workable.[1] In addition, the sequence includes coarse grits, thin pebble beds and reddish and yellow sandstones.

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[1] *Rec.*, LX, 404 (1927).

[2] *Ibid.*, 370.

[3] Gerth. *Proc. Kon. Akad. Wetensch. Amsterdam*, XXXIX, No. 7 (1936).

(b) BARAKAR STAGE.

Lower boundary.—In places the Barakar, a stage which derives its name from a river in the Raniganj coalfield, not only rests quite conformably upon the Talchirs, but the two groups pass into each other. Wherever this happens, it is obvious that the lowest beds of the Barakar stage are taxially equivalent to the Karharbaris. This complete concordance between the Talchirs and Barakars, however, is not always persistent even in the same coalfield, and evidence of slight unconformity and erosion is not wanting. In the western parts of the Raniganj field, for example, there is no unconformity and the passage from the uppermost Talchirs into the basal Damudas is a gradual one though the transition occupies but a small thickness of strata, and in some places it is difficult to define the boundary ; in certain stream sections in other parts of the same field, on the other hand, a slight discordance can be detected between the Talchirs and Barakars, and in the northeast of the basin the former have died out and the Barakars, which have become considerably thinner, transgress on to the uneven Archæan floor. In the Jharia basin, the Barakars overlie the Talchirs with slight unconformity. In Karanpura, for long distances the Barakars, the local base of which is by no means a constant horizon, rest directly upon Archæan rocks without any intermediate Talchir beds. In the Aurunga field also—and in fact in several other Gondwana basins—this overlap of the Barakars on to the basement of metamorphic rocks takes place. The Barakar beds of the Ramgarh coalfield resemble the Karharbaris of Giridih in that they contain rolled fragments derived from the Talchirs.[2]

Thickness.—The thickness of the Barakar stage in the Jharia field, excluding the Hariharpur shales, the Petia sandstones and the Shibbabudih shales—three sub-stages which are thought to correspond to the Ironstone Shales of the Raniganj basin as delimited originally by Blanford—is estimated probably to exceed 2,000 feet;[3] if we include the three above-mentioned sub-stages, as Blanford did, the total comes to about 3,350 feet. In the Raniganj field it is 2,100 feet, in North Karanpura 1,500 feet and the same figure is quoted as a maximum for the Aurunga field, while the thickness in Ramgarh is said to be 3,000 feet. In the Tatapani coalfield there are 900 feet of Barakars but both lower and upper limits of the stage are here ill-defined ; for the Satpura area a doubtful figure of 500 feet is given. In the Bisrampur field of Chhattisgarh, these beds are reduced to something like 500 feet. In the Chanda area of the Godavari valley, the thickness of the Barakars is not more than 250 feet, but further southeast, near Bhadrachallam it is at least 600 feet.

Lithology.—The rocks of the Barakar stage as a whole are coarser than those of the Raniganj stage and, excluding the Boulder Bed, much coarser than the

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[1] K. P. Sinor, "Mineral Resources of Rewa State", p. 23 (1923).
[2] V. Ball. *Mem.*, VI, 113 (1867).
[3] C. S. Fox. *Mem.*, LVI, 31 (1930).

Talchir sediments. With the Talchir, the Barakar stage has an equally extensive range over the Peninsula but seems to have derived much of its material from a different source. It is composed of conglomerates, sandstones or grits of various kinds, shales and coal.

The pebbles of the conglomerates and pebbly sandstones, some of them ten inches across, consist largely of quartzite strongly suggestive of some of the Dharwar rocks and not of the Vindhyan sandstone which figures so typically in the material of the Talchir boulders ; in the Hingir coalfield of the Mahanadi basin, they include specimens of red jasper, a rock very characteristic, as we have seen, of the Bijawar series (Dharwar).[1] A typical Barakar rock is a conglomerate of small, well-rounded, white quartz pebbles in a matrix usually of white sandstones ; such pebbles, when weathered out and scattered over the surface, sometimes indicate the presence of the conglomerate where the actual rock is not exposed in section.

The sandstones of the Barakars are mostly light in colour, with brown red, yellow and other tints, varying to a pure white. They are often current-bedded, and typically coarse, with pebble horizons of quartzite as already noted. They are usually highly felspathic, consisting of grains of quartz and of felspar which, like that in other Damuda rocks but unlike that of the Talchir sandstone, is almost invariably kaolinised ; the weathered surface of these soft and rather massive rocks frequently exhibits small projecting knobs due to calcareous concretions. A whitish felspathic sandstone of this character is seen in localities as widely separated as Raniganj in Bengal and Bihar, and Chanda in the Central Provinces where it is well developed in the Godavari valley. Finer types of sandstone do occur but are not common. The basal Barakar bed in Karanpura is described as a breccia or a coarse grit with angular fragments of the metamorphic rocks on which it usually lies, as well as more or less rounded pebbles[2]; in Raniganj it is often a coarse sub-angular conglomerate or boulder bed.

Other beds comprise micaceous shaly sandstones or sandy shales, the latter often carbonaceous, with intercalated seams of coal of various quality, ranging up to 100 feet or more in thickness ; bands of ironstone make their appearance towards the top of the stage. In the Damodar valley, the most easterly exposures of the Barakars show a predominance of shales, grey, blue or black, frequently micaceous and more of less sandy, occasionally associated with argillaceous iron ore, often containing seams of coal, and not infrequently inter-stratified with hard flags. There is, in fact, the same coarsening of the Barakar deposits westwards up the Damodar valley as occurs in the case of the Talchirs ; from Raniganj to Karanpura the conglomeratic bands become thicker and more frequent and contain larger pebbles, whilst there is in general a deterioration in the quality of the coal.

Good building-stone is obtainable from the massive Barakar sandstones. In the Rajmahal hills, the stage also includes china clays of good quality, especially at Mangal Hat and Patarghatta (Patharghata).[3]

The Barakar has been the greatest coal-bearing epoch in the geological history of India. The coals of the stage vary much in quality and character in the different fields ; they have already been discussed under the general heading of Damuda, and will receive further attention in the chapter on individual Gondwana outcrops.

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[1] C. S. Fox. *Mem.*, LIX, 174 (1934).
[2] A. Jowett. *Mem.*, LII, 43, 44, 49, 50, etc. (1925).
[3] Murray Stuart. *Rec.*, XXXVIII, 133 (1909).

Flora.—With regard to the flora, as distinct from that of the Karharbari, the two groups of Sphenophyllales and Cycadophyta attain greater importance, and the Equisetales are supplemented by the genus *Phyllotheca.*[1] A list of Barakar plants will be found in the table on page 934-9. From beds in Mirzapur, believed to be of Barakar age, have been obtained some vegetable spores and some papillate, stomatose cuticles closely resembling *Lebachia* ; the spores include one-winged, two-winged and unwinged varieties.

(c) IRONSTONE SHALES.

Above the Barakar stage in the Raniganj coalfield of the Damodar valley, there is found a middle stage, unusually artificial in its individuality but remarkably uniform in its lithology. It comprises a great thickness of fine, dark grey or black, carbonaceous shales with numerous bands and nodules of argillaceous iron ore varying in thickness up to about a foot. These clay-ironstones vary laterally and are often lenticular ; superficially, they become oxidised to a reddish brown colour, but below a depth of ten feet or so the iron, or at least a part of it, is seen to be present in what was no doubt its original form, *i.e.*, carbonate. Some of this mixture of carbonate of iron and clay is carbonaceous, producing that variety of clay-ironstone known as " black-band ". Towards the base, these Ironstone Shales, as the stage is named, become more sandy and micaceous and intercalations of sandstone occur amongst them. As a result of the slow disintegration of these shales, the tract covered by them is barren and frequently elevated ; the rocks, however, are not as a rule well exposed on the surface, though their presence may be indicated by scattered fragments of ironstone. In the good ores, which were used until the beginning of the first Great War by the Bengal Iron & Steel Company in their furnaces at Kulti, the average percentage of iron is between 40 and 45 ; these richer ores occupy the 10-foot oxidised zone, the sideritic bands deeper down being unattractive both in quality and abundance for smelting purposes. Since early times, the surface ores have been employed by local *agorias.* Including the Begunia shales and the Begunia sandstones, the Ironstone Shales in Raniganj have a thickness of 1,350 feet.[2] The junction with the Barakars is rarely visible but when not faulted it is a conformable one ; the passage of the Barakars up into the Ironstone Shales is described as much more gradual than that of the latter stage up into the overlying Raniganj stage. Plant remains are abundant but not well preserved ; amongst them have been recognised : *Gangamopteris cyclopteroides, Glossopteris indica, G. ampla, G. damudica* (perhaps the equivalent of *G. indica*), *Cordaites* (*Noeggerathiopsis*) *hislopi*, and many others (*see* Table, p 934-9).

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[1] B. Sahni. *Proc. As. Soc. Beng.* New Ser., XVII, clxi (1921).

[2] The supposed unconformity below the Begunia sandstone has been shown by Fox, in the light of fresh quarry sections, to be a deceptive phenomenon caused by current-bedding of an extremely coarse grade in this sandstone ; this incentive to draw the boundary below the Begunia sandstone no longer existing, Gee has preferred to draw it at the top, thus including this sandstone, which is of typical Barakar aspect, together with some thin shales just below, within the Barakar stage and not in the Ironstone Shales where they had been placed by Blanford. Blanford's boundaries are retained provisionally in this work until it can be decided whether any modification of the fossil lists should accompany the change made in the boundaries of the stage.

The Ironstone Shales, as such, are not found in the Jharia field, but are thought to be represented by three of the four sub-stages which make up the "Barren Measures" of Fox; the latter comprise the following:—

	Feet.
4. Mahuda sandstone	650
3. Hariharpur shales	150
2. Petia sandstones	600
1. Shibbabudih shales	600

Numbers 1, 2 and 3 correspond to Blanford's Ironstone Shales, but it is No. 3 alone which is the equivalent of that stage as restricted by Gee. The "Barren Measures" are described as similar in all respects to the Barakars, down into which they pass, except for the absence in the former of workable coal seams and the conspicuity of carbonaceous shales.[1] In the "Barren Measures" of the Jharia field, sideritic layers are not markedly developed.

In the Bokaro and Karanpura coalfields, it is possible to recognise a middle Damuda stage between the Barakar and the Raniganj, but exceedingly difficult to establish precise horizons for the separation of the three subdivisions. Hughes speaks of the Ironstone Shales in these two fields as conformable to the Barakars but as being overlapped by the Raniganj stage; Sir Lewis Fermor prefers to regard the Ironstone Shales in the Bokaro field as an uppermost division of the Barakars since both shales and sandstones are of typical Barakar aspect, and thinks there is reason for supposing that the ironstone nodules of the so-called Ironstone Shales are of superficial origin. The Ironstone stage has been identified in the Karanpura field,[2] and is said to cover a very small area in Ramgarh. In the Aurunga, Hutar and south Rewah coalfields, owing to the absence of workable coal seams in the Raniganj stage, it is impossible, in the present state of our knowledge, to recognise a middle Damuda subdivision. The Motur beds of the Satpura region in the Central Provinces are thought to include the equivalents of the Ironstone Shales of Raniganj, and are described on page 956.

(d) RANIGANJ STAGE.

Damodar valley, Palamau, Sarguja and southern Rewah.—The highest stage of the Damuda series derives its name of Raniganj from the principal town of the coal-mining district of Burdwan, where it attains its maximum economic importance. Farther west, in Jharia, it is greatly outclassed by the Barakars, and farther still up the Damodar valley, in the Bokaro and Karanpura basins, it is of no importance as a coal-bearing formation. Workable seams, in fact, are not found in the Raniganj stage outside the Damodar valley, with the unimportant exceptions of Darjeeling and perhaps the Rajmahal area. Like the Barakar the Raniganj stage of the type area comprises a great thickness of sandstones, shales and coal seams. As a rule, the sandstones are finer in texture than those in the Barakar stage and can usually be distinguished on lithological grounds alone.[3] With occasional exceptions, the coarse, white, felspathic grits and conglomerates of the Barakars are wanting. The majority of the Raniganj sandstones are grey or greenish in tint, even textured, medium grained, obliquely laminated and occurring in thick massive beds ; some of the lower types include numerous small grains of pink felspar, usually kaolinised. Intercalated within these sandstones are lenticular bands of hard, fine-textured, sideritic sandstone, which weathers out at the surface in nodular fragments. Shales form a smaller proportion of this stage than they do of the Barakar. Beds of this kind include micaceous shaly sandstones, sandy shales, and dark grey shales with occasional ironstone bands ; some of the shales are carbonaceous. Good quality fire-clay is not found in the Raniganj stage.

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[1] C. S. Fox. *Mem.*, LVI, 77 (1930).

[2] A. Jowett. *Mem.*, LII, 125 (1925). In South Karanpura, Feistmantel collected the following plant remains from what he thought were the Ironstone Shales, but the fossils obtained seem to belong entirely to the Raniganj stage:—Equisetaceous stems, *Tæniopteris danaeoides*, *Glossopteris angustifolia*, *G. damudica*, *G. retifera*, *G. conspicua*, *Gangamopteris cyclopteroides*, and *Cordaites* (*Noeggerathiopsis*) *hislopi* (*Pal. Ind.*, Ser. XII, vol. IV, Pt. 2, pp. 14-15 (1886).

[3] E. R. Gee. *Mem.*, LXI, 48 (1932).

An examination by Mr. A. K. Banerji of the heavy mineral constituents of the sandstones from four separate horizons showed that these beds are more or less arkose with a high proportion of felspar, microcline being in all cases present. There is an entire absence of such metamorphic minerals as kyanite, sillimanite, andalusite, staurolite, cordierite, etc. ; magnetite and ilmenite are also absent. The majority of the heavy minerals are those associated with igneous rocks, such as garnet (predominant), zircon, rutile, biotite, tourmaline, monazite, apatite, and an undetermined bluish mineral. The facts that these heavy minerals show no noticeable change in character in any of the four horizons and a persistent predominance of garnet, and that all types, especially the garnets, maintain identical physical properties throughout, suggest that the Raniganj sandstones were all derived from the degradation products of the same set of rocks and that there was no change in the direction of drainage throughout the Raniganj epoch, a conclusion already deducible from the absence of any evidence of inter-formational unconformity.[1] According to Mr. M. C. Poddar, Raniganj can be easily distinguished from Barakar sediments by their heavy mineral contents.[2]

The coal seams, ranging up to an individual thickness of over 40 feet, show considerable lateral variation both in quality and thickness, but the changes are described as being much more gradual and the seams as much more constant in character than is the case in the Barakars ; as in the latter stage, the coal is composed of alternately bright and dull layers. The well-known Dishergarh seam, containing perhaps the most valuable high-volatile coal in India, is a member of the Raniganj stage, and is found in the western parts of the Raniganj field. The general characters of Raniganj coal have already been enumerated.

Occasional boulders are met with in the lower Raniganj strata, sometimes in the coal seams. One of these, found in the sandstone roof of a seam, is itself composed of a finer-grained, reddish sandstone resembling certain Vindhyan types ; Gee suggests that it was transported to its present site on floating timber during the process of sedimentation.

A sphœrosiderite, of the nature of a "coal ball", was recently found in the Dishergarh seam of Raniganj and has been described by Mr. H. S. Rao .[3] It is reported to consist of a heavy black block, some 360 cubic centimetres in volume, made up of a number of more or less spherical brown masses of well-preserved wood, most of them about one centimetre in diameter, in a matrix of coal. The specimen was originally a single block of wood ; it is shown by the fact that there is in places a clear transition between the balls of wood and the coaly matrix and also by the fact that in all the woody fragments the tissues are similarly orientated. The wood has been identified as belonging to a new species of *Dadoxylon—D. parbeliense* Rao. The original block evidently became cracked into cuboidal fragments, which ultimately assumed a spheroidal shape, the cracks becoming filled up with coaly substance.

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[1] E. R. Gee. *Mem.*, LXI, 49 (1932).

[2] *Quart. Journ. Geol. Min. Met. Soc. Ind.*, VII, 45 (1935).

[3] H. S. Rao. *Rec.*, LXIX, 174-183 (1936).

As a general rule, the Raniganj beds are conformable to the Ironstone Shales, but the higher stage oversteps the latter with a slight unconformity and rests on the Barakars in the Bokaro coalfield, near Hazaribagh. In the case of the Karanpura field, the junction between the Raniganj and Ironstone Shales is usually very clearly defined ; the lower boundary of the former is, in fact, less discernible when it rests directly on the Barakars.[1]

In this stage, plants are abundant and comprise nearly all those of the Barakar besides a number of species unknown from any lower horizon. The forms obtained from the Raniganj of the Damodar valley and from its equivalents in Nagpur, the Narbada valley and south Rewah have been listed in the table on page 934-9. *Gangamopteris* appears in the Indian flora for the last time, while *Glossopteris* attains its maximum development, several of the species being restricted to this stage. The silicified tree trunks found in this stage have already been described, and are common in the Jharia as well as in the Raniganj coalfields ; fossil wood of smaller dimensions is plentiful in the topmost of the Raniganj sub-stages.

In the Raniganj field, this stage attains a maximum development of between 3,000 and 3,400 feet, but the next stage in ascending order rests upon a denuded surface of Raniganj beds, so that the uppermost horizons of the latter formation are evidently missing. In the extreme east of the Raniganj basin, the basal sandstones of the Raniganj measures, as well as the Ironstone Shales, have thinned out and the lowermost coal seams of the middle and western parts have disappeared. Some twenty miles west of the western margin of the Raniganj basin, rocks of the Raniganj stage are exposed in the Jharia coalfield but in this area the formation, though still containing a few coal seams of value, is less important than it is in the lower field and is only about 1,840 feet thick ; how much of it has been removed by erosion, however, it is impossible to say since the next stage in the Gondwana sequence, the Panchet, is absent. Nevertheless, according to Fox, the five sub-stages of the Raniganj beds in the Raniganj field have been recognised (under different names) in Jharia ; assuming this correlation to be correct, we must conclude, therefore, that there is a general and uniform thinning of the stage in a westerly direction. In the Bokaro field, the coal seams of the Raniganj stage are economically unattractive. Further westward up the Damodar valley, in the Karanpura coalfield, though outcrops of coal or carbonaceous shale are frequently to be met with in the Raniganj formation, the former are thin and there are very few seams of workable thickness. In the Aurunga field, the Raniganj stage has a maximum thickness of 1,000 feet in the eastern parts but is wanting in the west ; it contains a thin seam of coal of too poor a quality to be of any value. Still further west, in the Tatapani, and south Rewah coalfields, even the lithological character of the stage has changed, the grey and carbonaceous aspect of the shales has given place to the reds and browns of the Kamthi type, and the plant fossils are the only guides for the recognition of the beds.[2]

Areas outside the Damodar valley.—Beyond the limits of the Damodar drainage, the Raniganj stage appears to be represented by groups of different mineral character. It has been recognised palæontologically in southern Rewah under the name of the Pali stage or Pali-Daigaon stage, lying upon the Barakars. In the Mahanadi and Godavari drainage areas, the Barakars are overlain by a thick succession of beds which have been described in different areas by different names ; the lowest stage of these beds in the Mahanadi valley is spoken of as the Hingir, and that in the Godavari as the Kamthi, both of them proximate equivalents of the Raniganj. The Bijori stage of the Satpura region corresponds in its flora with the Raniganj, and the Chintalpudi and Dummapett Sandstones of the east coast may represent much the same stratigraphical levels.

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[1] A. Jowett. *Mem.*, LII, 127 (1925).

[2] C. S. Fox. *Mem.*, LVIII, 206-207 (1931).

Pali stage.—In southern Rewah, the Barakars are overlain by a succession of rocks whose relationships have not yet been completely determined but which were considered by Mr. T. W. H. Hughes to range up to identifiable Jabalpur beds. These so called "Supra-Barakars" are ferruginous in character and include a set of beds to which has been given the name of Pali, taken from a village near Birshinghpur railway station. By reason of a lithological consanguinity, the Pali beds were at first grouped with the beds found at Parsora. Fox, however, has discovered that two separate rock stages are involved, the Parsora being younger than the Pali. The latter stage includes the beds at Daigaon, Karkati and elsewhere, as well as those at Pali, and has yielded : *Glossopteris indica*, *G. damudica*, *G. cordata*, *G. angustifolia*, *Schizoneura* sp., *Vertebraria indica*, *Sphenopteris polymorpha*, the one-winged spore *Hymeno-zonotriletes triangularis* Mehta, the two-winged spores *Pityosporites ganjrensis* Mehta and *P. johillensis* Mehta, the three-winged spore *Brachytrilistrium rewai* Mehta, and the wood *Mesembrioxylon paliense* Mehta. The Pali-Daigaon beds are regarded as the equivalents more or less of the Kamthi or Raniganj stage, a correlation formerly favoured by Mr. Hughes ;[1] whether there is any discordance between them and the underlying Barakar coal measures is not certain.[2]

In the Umaria area, Gee found the supra-Barakar rocks divisible into a lower group of grey, yellow and orange, soft, felspathic sandstones, medium to coarse in texture, alternating with brightly tinted clays, usually of red, purple or light green colour, and an upper sub-division of similar soft sandstones including beds of well-rounded quartzite pebbles set in a soft sandy matrix;[3] some, if not all, of these beds are presumably the equivalents of the Pali.

LOWER GONDWANAS OF THE SATPURA AREA.

Succession.—In the Satpura ranges, south of the Narbada, the Lower Gondwanas are fully represented and immediately south of the Pachmarhi plateau must be quite 8,000 feet thick.[4] The succession is remarkably like that found in Bengal and Bihar. The Talchir and Barakar stages are easily recognisable, enclosing between them beds which probably correspond to the Karharbari phase or sub-stage. The Barakar is followed by a succession of rocks which, although forming what appears to be a single unit, have been divided into two stages, the Motur below and the Bijori above. In a general way, these two stages, which everywhere pass vertically one into the other, are the taxial equivalents of the Ironstone Shales and Raniganj stage of the Damodar valley. The same distribution of carbonaceous matter is also seen in both areas, the coal-less Ironstone Shales and equally barren Moturs contrasting with the coaly or carbonaceous Raniganj beds and Bijoris. The line of division between the Motur and Bijori stages has been selected by Crookshank as that separating a lower sub-division in which fossils are rare, and an upper in which fossils are common.[1] In the Tawa area, the Barakar rocks appear to pass up into the Motur, but a slight unconformity is reported between the two formations in the Pench valley.

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[1] *Mem.*, XXI, Pt. 3, 73 (1885).
[2] C. S. Fox. *Mem.*, LVIII, 172-173 (1931) ; *Ibid.* LIX, 179 (1934).
[3] *Rec.*, LX, 408 (1927).
[4] C. S. Fox. *Mem.*, LIX, 245 (1934).

Motur stage.—The Motur beds, named after a village situated about twelve miles S.S.E. of Pachmarhi, consist of thick, soft, coarse, earthy, grey and brown sandstones, with occasional lenticles of clay and shale, the latter usually sandy and very rarely carbonaceous. The sandstones are as thick and massive as those in the Pachmarhi beds higher up in the Gondwana sequence, but differ from these principally in the prevalence among them of grits with abundant chips of felspar, the presence of clay or shale lenticles, and the absence of the conglomerates and ferruginous partings so frequently found in the Pachmarhi sandstones. Furthermore, the latter give rise typically to precipitous scarps, rarely seen in the case of the Moturs, and produce a more barren form of débris than the stiff white soil of the older rocks. The clays of the Motur stage are calcareous and, when unweathered, are buff to pale green in colour, but nearer the surface become mottled and red, the change in colour being accompanied by a liberation of carbonate of lime in a nodular form ; in colour and character they are often very like the Talchir clays.[2] The thick beds of red clay in the Moturs of the Pench valley have nothing comparable in the Tawa river section. The extremely scarce fossils in the Moturs comprise *Glossopteris indica* and *G. conspicua*, found in a lenticle of shale, and many carbonaceous tree trunks observed in some of the massive sandstones. Silicified wood has also been collected from near the base of the stage in both the Pench valley and upper Tawa areas.

No close estimate of the thickness of the Motur stage has been made, but in the section southwest of Pachmarhi, Crookshank calculates the total thickness of the Moturs and Bijoris to lie between 4,500 and 6,500 feet. Of this 600-800 feet belong to the Bijori, leaving from 3,900 to 5,700 feet for the thickness of the Moturs ; a mean figure for the latter would thus be 4,800 feet. In the Pench valley area, the Moturs are thought to exceed 2,000 feet ; the underlying Barakars are here reduced to between 350 and 400 feet, and are believed to rest conformably upon the Talchirs.[3]

Bijori stage.—The uppermost part of the Damuda series in the Satpura region is well exposed in the upper Denwa valley, at the southern base of the Mahadeo (Mahadeva) or Pachmarhi hills. The outcrop is overlooked by the cliff which forms the southern limit of the range, and extends for a length of over sixty miles, between the exposure of Motur beds to the south and that of the Upper Gondwanas of the hills to the north. Two small faulted inliers have been noted on the north side of the range.

The rocks of this stage, named after the village of Bijori in the Chhindwara district, are characteristically Damuda in aspect, but vary greatly from place to place. They comprise shales, which are occasionally carbonaceous, micaceous flags and sandstones ; coal seams are also present but no serious attempt to exploit them has so far been made. From east to west, there is an increase in

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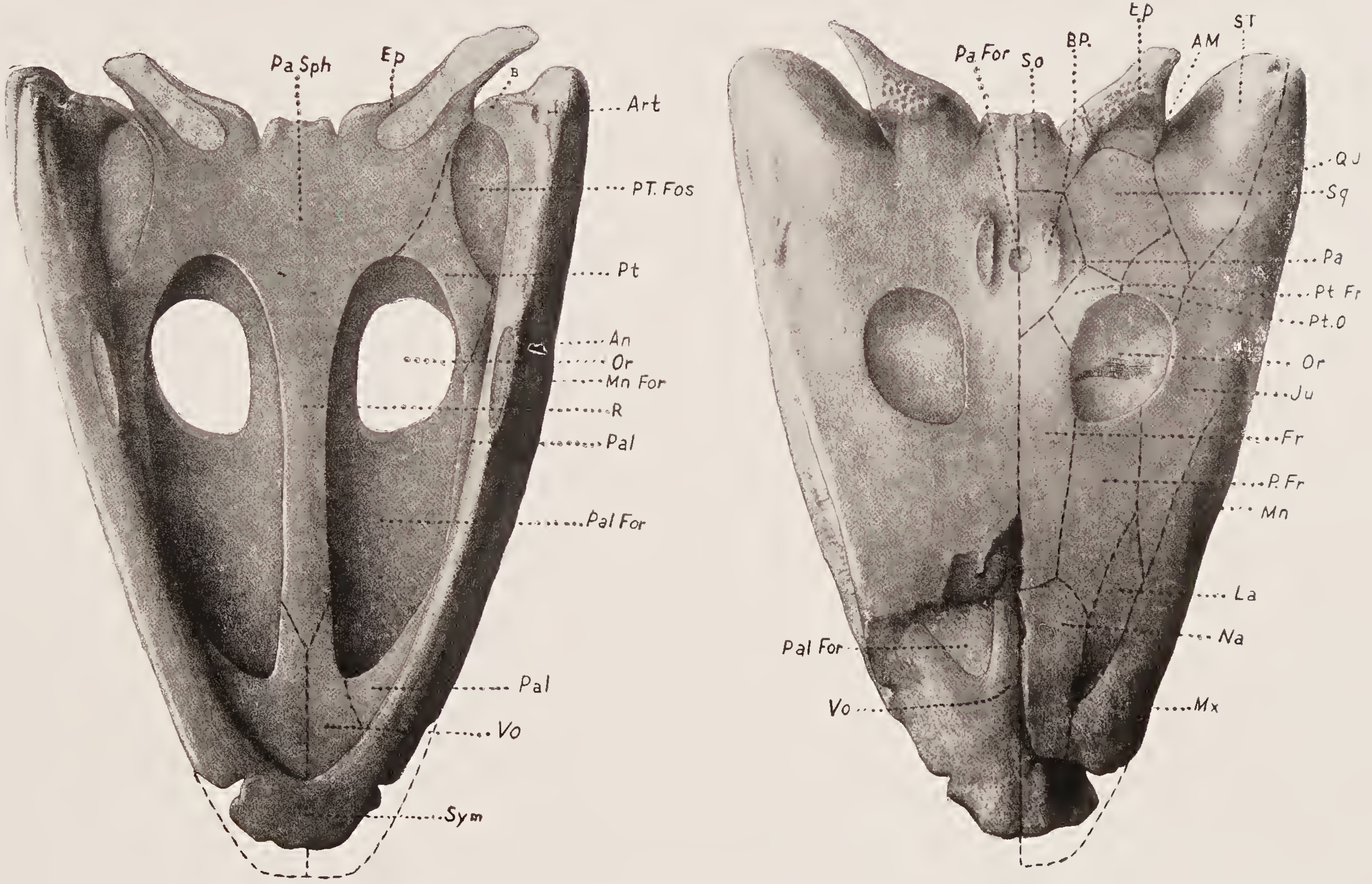
[1] *Mem.*, LXVI, 213 (1936).

[2] C. S. Fox. *Mem.*, LIX, 248 (1934).

[3] C. S. Fox. *Mem.*, LIX, 278 (1934).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BIJORI LABYRINTHODONT.

Gondwanosaurus bijoriensis Lyd.

G. M. Woodward del.

G. S. I., Calcutta.

arenaceous beds, the predominant rocks near the western end being massive sandstones. From the Denwa clays, higher up in the stratigraphical scale, those of the Bijori differ in being more shaly and micaceous and in being fossiliferous. Minor faults, most of them orientated E.N.E.-W.S.W., are recorded. The beds roll in places but dip eventually northwards under the Pachmarhi stage.

The most important fossil found in the Bijori beds is the skull and a considerable portion of the axial skeleton of a labyrinthodont allied to *Archegosaurus*, described by R. Lydekker under the name of *Gondwanosaurus bijoriensis*;[1] this is the only vertebrate fossil yet obtained from the Damuda series.[2] *Gondwanosaurus* is a more specialised type than *Archegosaurus*, which is chiefly confined to the Carboniferous but ranges up into the Lower Permian, the specialisation indicating an approach to the higher labyrinthodonts like *Mastodonsaurus* and *Labyrinthodon*; such evidence would place the Bijori beds well within the Permian. This is confirmed by the general facies of the flora, which corresponds best with that of the Raniganj stage in Bengal. The following plants from the Bijori stage have been identified[3] :—

Equisetales.
  Schizoneura gondwanensis Feistm.,
Sphenophyllales.
  Sphenophyllum (Trizygia) speciosum Royle.
Filicales.
  Sphenopteris (Dicksonia) sp.,
  Cladophlobis roylei Arb., *Pecopteris phlegopteroides* (Feistm.).

Cordaitales.
  Cordaites (Noeggerathiopsis) hislopi Bunb.,

Pteridospermœ.
  Glossopteris damudica Feistm. (perhaps equivalent to *G. indica*).
    ,, *retifera* Feistm.,
    ,, *angustifolia* Brongn.,
    ,, *conspicua* Feistm.,
    ,, *indica* Schimp. (including "*G. communis* Feistm.").
  Gangamopteris cyclopteroides Feistm.,
    ,, *cf. whittiana* Feistm.,
  Samaropsis cf. *parvula* Heer.,
  Vertebraria indica Royle,
  Tree trunks.

These plant remains are frequent, especially in the argillaceous rocks, the commonest being the various species of *Glossopteris*, *Schizoneura gondwanensis*, and *Cladophlebis roylei*. The survival of *Gangamopteris* is of interest, since that genus usually disappears at a lower horizon in the Damuda succession.

The junction with the overlying Pachmarhi sandstone is an unconformable one and is well seen to the east of Tamia. The unconformity is substantiated by the irregular manner in which the junction rises and falls, by a sudden change in lithology, topography and flora, by a change of dip in some places, and by the occurrence, in the Pachmarhi sandstone of certain localities, of large boulders of clay similar to that found among the Bijori rocks. Where the Bijoris are overlain by the Lametas and Deccan Trap, there is a marked unconformity, augmented by the contrast between the *Glossopteris* flora of the first and the fossil palm trees of the Lametas. As we have seen, the thickness of the Bijori stage is between 600 and 800 feet southwest of Pachmarhi, but elsewhere it has been estimated at about 4,800 feet.

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[1] *Pal. Ind.*, Ser. IV, Vol. I, Pt. 4, 1-14 (1885).

[2] The Mangli beds of Chanda, in which *Brachyops laticeps* occurs, are correlated with the Panchets.

[3] O. Feistmantel. *Rec.*, XII, 76 (1879); H. Crookshank. *Mem.*, LXVI, 219 (1936).

"Almod beds".—The highest beds of the Lower Gondwanas at one point below the southern escarpment of the Pachmarhi plateau were at one time distinguished under the name of Almod, from a village at the base of the scarp. The beds underlie the Pachmarhi sandstones and pass vertically and horizontally into typical Bijoris. They are slightly more arenaceous than is usual in the upper parts of the Bijori stage, but the discovery by Dr. Crookshank in at least one place of fragments of *Glossopteris* exactly like the commonest Bijori variety of that plant, puts the Bijori age of the beds beyond dispute.

LOWER GONDWANAS OF THE MAHANADI BASIN.

In the various coalfields of the Mahanadi basin, the Barakars in most places rest upon the Talchirs, in the Kumasia and Bisrampur areas almost horizontally;[1] in the Hingir field, however, they rest directly upon Archæan gneisses. In the Talcher field at the southeastern end of the basin, the Barakars with their included coal seams have an estimated thickness of 1,800 feet, but towards the other extremity of the basin, in the Bisrampur area, this figure is reduced to something like 500 feet. Overlying the Barakar beds unconformably in several of the fields is a sequence consisting mainly of red sandstones and grits which have been spoken of as the Hingir stage and which are probably equivalent to the Kamthi facies of the Raniganj (*vide infra*) ; in the Rampur (Ib river) field, these beds resemble the Mahadevas and are barren of coal seams, but undoubted Mahadeva strata are recognisable, lying above them. The group consists of coarse, ferruginous sandstones and conglomerates, with beds of red shale but no carbonaceous deposits. The Hingir sandstones usually possess a matrix of red ochreous clay, which is also present in the form of layers in the sandstone. In the shales have been found the following fossil plants, in which the carbon has been completely replaced by iron[2] :—

Equisetales.
    Schizoneura gondwanensis Feistm.,
    Vertebraria indica Royle,
    Sphenopteris polymorpha Feistm.,
    Pecopteris sp.
Pteridospermæ et Filicales.
    Glossopteris indica Schimp. (including "*G. communis*").,
    ,, *browniana* (?) Brongn.,
    ,, *angustifolia* Brongn.,

In the Talcher area, the beds overlying the Barakar, some 1,500-2,000 feet in thickness, have been assigned doubtfully to the Pachmarhi stage of the Mahadeva series, but may be the equivalents of the neighbouring Athgarh Sandstone (Rajmahal series) ; if either correlation be correct, there must be a large stratigraphical break between the beds and the underlying Barakars, corresponding to a discordance apparent in the western part of the field. In the fields between Sarguja and Bilaspur, the supra-Barakars were at first regarded as Mahadevas but later on as Kamthis (Hingirs), but there is no fossil evidence to decide the question ; the beds are believed to be unconformable to the coal-bearing Barakar beneath.

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[1] C. S. Fox. *Mem.*, LIX, 215 (1934).

[2] V Ball. *Rec.*, X, 171 (1877).

KAMTHI BEDS OF THE WARDHA-GODAVARI BASIN.

In the Wardha-Godavari basin, the beds which overlie the Barakar stage have been described under the title of Kamthi, a name derived from the military station twelve miles northeast of the town of Nagpur or rather from a village on the opposite side of the Kanhan river, where a famous quarry has yielded a large number of fossils. From the Wardha valley to within a few miles of the deltaic deposits of the east coast near Ellore, the Gondwana system extends in an unbroken stretch, represented by its various sub-divisions but always pre-eminently by the Kamthis, here known originally as the Chintalpudi and Dummapett sandstones; towards the coast, the Kamthis are covered unconformably by plant beds of probably Jurassic age (Golapillis), followed by marine deposits of Lower Cretaceous age.

The Kamthi rocks of the type area near Nagpur consist of conglomerates of quartz pebbles, grits, sandstones and shales. The grits are usually soft and argillaceous but are sometimes sufficiently hard and siliceous to be quarried for quernstones; they are frequently iron-stained and often intersected by hard ferruginous bands of a dark brown colour. Among the sandstones, which vary greatly in character and colour, are fine-grained micaceous varieties, in colour white with blotches and irregular streaks of red. One of the most typical members of the formation is a very fine, massive and homogeneous mudstone, yellow in fresh sections but becoming red when exposed; it passes into red shale. Another characteristic bed is a hard, grey grit or sandstone, ringing under the hammer and breaking with a conchoidal fracture. Outside the type area, the Kamthis of the Godavari consist mainly of soft, porous, brown or white sandstone, conglomeratic in places, often with hard, ferruginous bands, a few red shales, and some red or green clays which prevail chiefly in the upper portions of the stage; here and there, however, a band of one of the characteristic rocks is met with towards the base of the formation.

In the Godavari valley, trough faulting with a N.W.-.S.E., trend continued during the deposition of the Gondwana sediments, which were not invariably restricted to the main valley, as can be seen, for example, in the Bandar coalfield. The floor of the Gondwanas is here composed largely of unfossiliferous Pakhal limestones and shales and Sullavai sandstones; judging from the general parallelism between the belts of all sediments exposed in the valley, whether old or young, the faulting was responsible for the preservation not only of the Gondwanas but of the underlying sedimentary rocks of Purana age. In the Nagpur area, Talchirs and Kamthis appear from below the Deccan Trap, lying upon the Archæan. Inliers are seen in the Trap to the west, one of them below the Gawilgarh lava scarp; these Gawilgarh sandstones are almost certainly of Kamthi age.

The thickness of the Kamthi stage has not been determined but is undoubtedly considerable; the 5,000-6,000 feet suggested in the preceding edition of this Manual[1] is, however, probably far in excess of the truth. Sometimes the beds of this stage appear to lie conformably upon the Barakars but the concordance is apparent only, for the Kamthis overlap in a most irregular manner not only the Barakars but also the Talchirs and even the Sullavais, transgressing in some places on to the Pakhals. The Talchirs and Barakars of this region, in fact, crop out at somewhat rare intervals and from their distribution, appear to have suffered considerable erosion before the deposition of the Kamthi sediments; evidence of such discordance is seen, for example, in the Rajur or Wun coalfield, and also in the Bandar coalfield. As already mentioned, the Hingir beds of the Mahanadi valley, which are generally accepted as the equivalents of the Kamthis, appear to rest unconformably on the Barakars in more than one locality.

The fossil plants of the Kamthi stage comprise the following species[1] :—

Equisetales.
  D. *Phyllotheca indica* Bunb.,
Pteridospermæ et Filicales.
  D. *Vertebraria indica* Royle.,
  D. P. *Glossopteris indica* Schimp.,
  D. ,, *damudica* Feistm. (*vide* remarks in table, p. 936),.
  ,, *stricta* Bunb.;
  ,, "*leptoneura*" Bunb. (probably a variety of *G. angustifolia*),

  D. *Gangamopteris cyclopteroides* Feistm. ("*G. hughesi* Feistm.").
  Pecopteris sp.
Cycadophyta.
  Tæniopteris (*Angiopteridium*) cf. *macclellandi* (Oldh.),
  D. ,, *danæoides* Royle,
  D. ,, *feddeni* (Feistm.),
Cordaitales.
  D. *Cordaites* (*Noeggerathiopsis*) *hislopi* Bunb.,
  D=Found also in the Damuda series of Bengal and Bihar.
  P=Found also in the Panchet series.

Of the Bengal and Bihar species, all are found in the Raniganj stage, but not all in the stages below ; *Tæniopteris macclellandi* has been found in the Rajmahal series of the Upper Gondwana. The character of the flora would lead us to regard the Kamthis as unquestionably belonging to the Lower Gondwana and homotaxial with the Raniganj stage ; from their great thickness, they might be expected to include part of the Panchet series, but there is no palæontological evidence of this. The chief peculiarity which distinguishes the Kamthi from the Raniganj or the Bijori is the absence of carbonaceous deposits or even carbonaceous markings. In other Damuda sub-divisions, with the exception of the Ironstone Shales, the plant remains generally retain a portion of their original carbon, but this is very rarely the case amongst the Kamthis.

III. PANCHET SERIES AND ITS EQUIVALENTS

The term Panchet is derived from an important *zamindari* in the Raniganj coalfield and form a large hill of the same name, the basal portion of which is made up of Panchet beds. In order to include within the limits of the Lower Gondwana two stages which are found, one in the Pranhita valley and the other in southern Rewah, and whose fossil contents place them above the Damuda but within the lower division of the Gondwana system, Dr. Cotter initiated a scheme whereby the term Panchet series included a basal Panchet stage, followed respectively by the Maleri and Parsora stages. More recent work, however, seem to indicate that the Maleri belongs to the Upper Gondwana, and that the Parsora may be equivalent to some part of the Panchet group of Bihar and Bengal. The conclusion has also been drawn that the Mangli stage of the Wardha valley belongs to Panchet. The flora of the Panchet beds and their equivalents is decidedly a poor one, and it is evident that the rich vegetation of the Raniganj epoch met with a check ; the Panchet and Parsora floras are those of a dry desert-like climate.

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[1] "*Glossopteris musæfolia* Bunb." has been omitted from this list.

The intrusion of mica peridotite, which seems to have affected the coalfields of Bihar, Bengal and Darjeeling after the deposition of the Panchet, but which may have commenced before the end of that period, will be described under the section on the Rajmahal series.

PANCHET SERIES OF BENGAL AND BIHAR.

In the type area of the Raniganj coalfield, the rocks of the Panchet series are seen overlying the coal-bearing Damudas in the southern and eastern portions of the field, though in the latter direction they are to a large extent hidden beneath alluvium. This easily recognised sub-division consists mainly of alternations of thick beds of coarse sandstone, some of them a hundred feet thick, and thin bands of fine red clay which vary from a few inches to twenty feet but rarely exceed twelve feet in thickness and are continuous over considerable areas. The red colour of the clay is probably due to the presence of hæmatite in fine powder coating the clay particles. The red clays sometimes contain thin bands or lenticles of white sandstone or clay ; irregular purplish grey limestone nodules are also sometimes included in the red clays. In Karanpura, the masses of red clay, enclosed within the current-bedded sandstones, are described as being in some cases blunt-ended instead of lenticular.[1] The Panchet sandstones are felspathic and micaceous, often of a white or greenish white colour, most irregularly and obliquely laminated, and evidently deposited by water flowing with a strong current[2], the felspar in the sandstone is occasionally undecomposed, a peculiarity never found in the Damudas though seen in the Talchirs. Conglomeratic beds, though uncommon, sometimes occur in the upper portion of the series, the pebbles comprising fragments of coal, shale and other material derived from Damuda rocks ; with this exception, the Panchet series is completely devoid of coal and carbonised plant remains.[3] Towards the base of the series occur thick, greenish, silty shales and greenish brown mudstones, strongly resembling certain Talchir types ; these beds contain hard 3-6-inch calcareous bands intercalated at intervals, and are interbedded with brown, micaceous, sandy shales or shaly sandstones. A few bands of impure limestone have also been noted in the lower half of the series. From the typical Damuda sediments the Panchets are distinguished by the presence of red clay, the absence of carbonaceous shales, and the more highly micaceous character of most of the sandstones. The red clays, which are very characteristic, probably correspond to breaks in the more normal sedimentation of a large river, caused by meandering.

The thickness of the Panchet series in the Raniganj area is about 2,000 feet loss than 1,400 feet in Bokaro, and 700 feet at its maximum in Aurunga. Mr. Gee found it possible to divide the series into two stages in the Raniganj area, the Maitur below, passing up into the Hirapur above. The former, 300-400 feet thick, is distinguished by its Talchir-like aspect from the latter which is characterised by coarser sediments, and softer, more micaceous sandstones. To the east of Asansol, borings seem to indicate that the Lower Panchet stage is missing, as well as the topmost beds of the underlying Raniganj stage, the Hirapur beds thus overlapping the Maiturs on to a probably denuded surface high up in the Raniganj stage.[4] In other places, the unconformity at the base of the Panchets is visible and distinct, being most marked in the Bokaro field, where the Panchets form the plinth of Lugu Hill and overlap the Raniganj stage westwards. In full sections, no great time interval is represented by the break between the Raniganj and Panchet formations. In fact, while in some places the Panchets completely overlap the Raniganj, in others, such as the Karanpura field, there is not only no visible unconformity but the uppermost strata of the Raniganj stage possess some of the Panchet characteristics, and the change from one to the other seems to have been more or less gradual. The Panchets are not present in the Jharia field; they are, however, found both west and east of it, and it is probable that a continuous sheet of these beds at one time extended across the Jharia area from Bokaro to Raniganj.

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[1] A. Jowett. *Mem.*, LII, 134 (1925).
[2] T. H. Huxley, *Pal. Ind.* Ser. IV, Vol. I, Pt. 1 (1865).
[3] E. R. Gee, *Mem.*, LXI, 54 (1932).
[4] E. R. Gee. *Mem.*, LXI, 55 (1932).

The most important animal remains hitherto observed in the Lower Gondwana rocks have been observed in the Panchets. In the upper portion of the series in the Raniganj coalfield, some 500 feet above the base of the formation, there is a well-marked conglomeratic band containing reptilian and amphibian bones, which are isolated from one another and sometimes slightly rolled; they include vertebræ and fragments of jaws with teeth, but are not very abundant.[1] The specimens, as described by Professor Huxley and Mr. Lydekker, together with a few others whose affinities are doubtful, comprise the forms listed below. The plants, which are rare and come from a slightly lower horizon, probably not far above the Raniganj-Panchet boundary, have been described by Dr. Feistmantel.[2]

Animalia.

- Pisces.
  - Fish scales, including those of *Amblypterus.*
- Amphibia.
  - Labyrinthodontia.
    - *Gonioglyptus longirostris* Huxley,
    - ,, *huxleyi* Lyd.,
    - *Glyptognathus fragilis* Lyd.,
    - *Pachygonia incurvata* Hux.,
- Reptilia.
  - Dicynodontia.
    - *Lystrosaurus orientalis* (Huxley).[3]
- Dinosauria.
  - *Epicampodon (Ankistrodon) indicum* Huxley.[4]
- Crustacea.
  - [*Cyzicus*] *Estheria mangaliensis* (?) Jones.
  - A doubtful brachyurous crab.

Plantae.

- Equisetales.
  - D. *Schizoneura gondwanensis* Feistm.,
- Filicales.
  - *Thinnfeldia odontopteroides* (Morr.)[5]
- Pteridospermae, Filicales aut plantœ incerta sedis.
  - D. *Vertebraria indica* Royle,
  - *Pecopteris concinna* Presl.,
  - *Cyclopteris* (?) *pachyrhachis* Göpp.,
  - D. *Glossopteris indica* Schimp (including "*G. communis*").
  - D. ,, *damudica* Feistm. (*vide* remarks in table, p. 936)
  - D. ,, *angustifolia* Brongn.,

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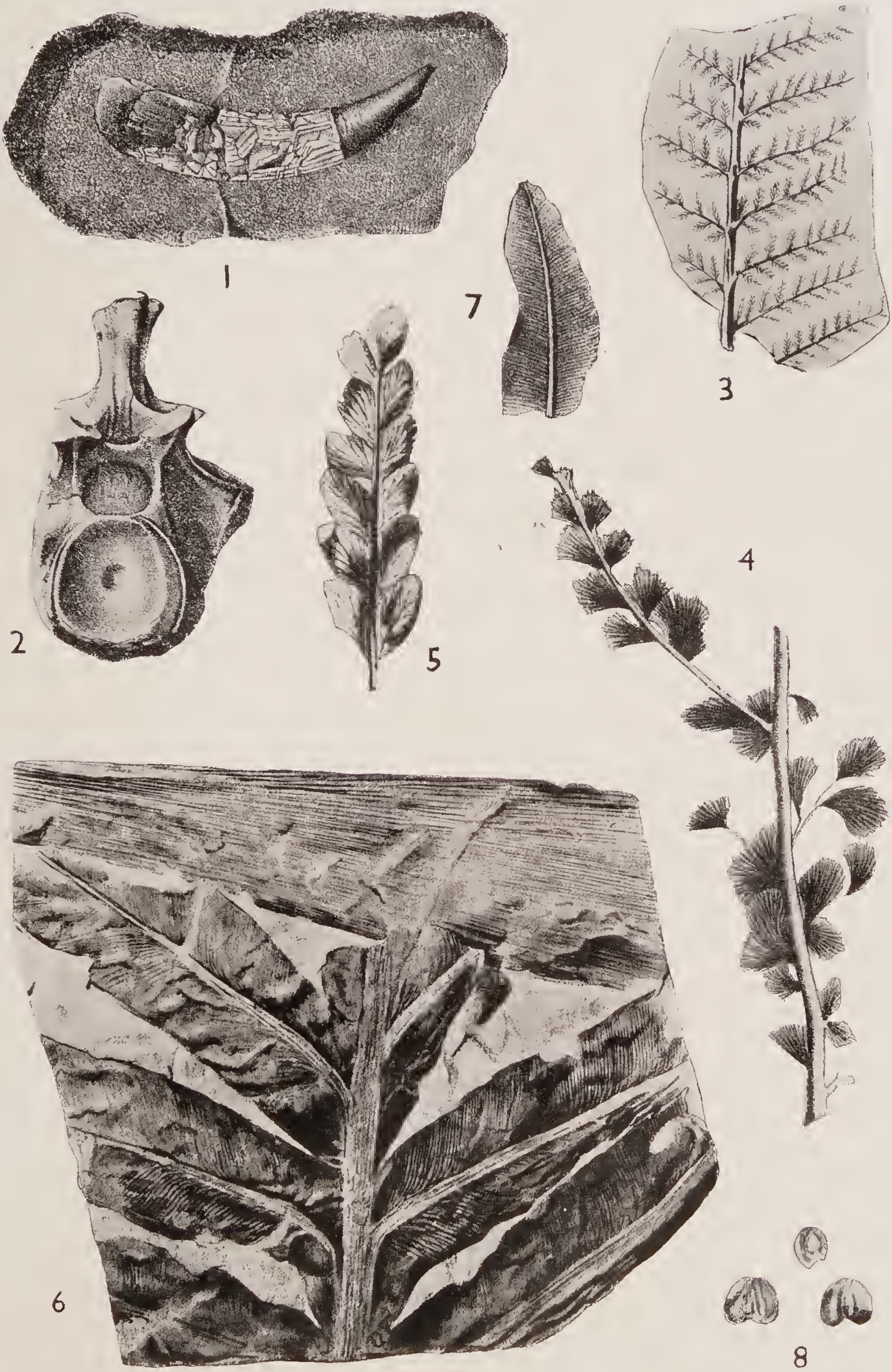
[1] W. T. Blanford. *Mem.*, III, Pt. 1, 129 (1861).

[2] *Pal. Ind.* Ser. XII, Vol. III, Pt. 2, 51-56 (1880).

[3] Originally *Dicynodon orientalis* Huxl.; Lydekker pointed out its affinities with Owen's genus, *Ptychognathus*, a name which however, had been previously employed for a crustacean genus. *Ptygosiagum* was proposed by Lydekker, but since it has been found that there are no essential differences between Cope's genus, *Lystrosaurus*, and Owen's "*Ptychognathus*" and since *Lystrosaurus* has the priority, the correct name for the Indian fossil would appear to be *Lystrosaurus orientalis.*

[4] H. C. Das-Gupta. *Journ. Proc. Asia. Soc. Beng*, New Ser. XXII, 217 (1926).

[5] The Panchet age of the horizon from which this form was collected is not quite certain.



PANCHET AND PARSORA FOSSILS.

1 & 2. *Dicynodon orientalis* Huxley. 3. *Pecopteris concinna* Presl. 4. *Cyclopteris pachyrhacis* Göepp. 5. *Dicroidium* (*Thinnfeldia*) *odontopteroides* (Morr). 6. *Danaeopsis hughesi* Feistm. 7. *Taeniopteris stenoneuron* (Schimp). 8. *Samaropsis* sp.

G. S. I., Calcutta.

Cordaitales.
Samaropsis cf. *parvula* Heer,

Cycadophyta.—
Tæniopteris (*Oleandridium*) cf. *stenoneuron* (Schenk).,
Cycad scales.

D=found also in the Damudas.

The probabilities are that the Panchet corresponds to the greater part, if not the whole of the Trias. The dicynodont, *Lystrosaurus*, characterises the basal beds of the South African Trias (*Lystrosaurus* zone); *Epicampodon*, although related to the upper Triassic dinosaurs, *Zanclodon* and *Thecodontosaurus*, was a particularly small type and its teeth show certain somewhat rudimentary features. The palæoniscid genus, *Amblypterus*, is met with elsewhere in deposits of Carboniferous and Permian age and is here a relic of the Palæozoic.[1] The flora, which has been collected almost entirely from a single locality in the Raniganj coalfield and from near the base of the formation, is scanty and less conclusive, but is not against a Bunter or Lower Triassic age, an allocation in agreement with the stratigraphical position of the series above the Upper Permian Raniganj stage. *Schizoneura gondwanensis*, an abundant form in the Panchets, links them with the Damudas; on the other hand, *Pecopteris concinna*, another plentiful species, and *Cyclopteris pachyrhachis* are more in favour of a Rhætic age.

There is a consensus of evidence to show that the Panchets are the accumulated sediments of a large river, apparently uninterrupted by the lakes or marsh flats which diversified its course from time to time during the preceding Damuda period. The meagre flora and the red clay beds suggest an arid climate which if it resembled to any close degree its counterpart in Australia, must have been warmer than the climate of modern temperate zones, judging from the abundance of dragonflies and the large size of other insects found in the Australian Trias.

MANGLI BEDS OF THE WARDHA VALLEY.

In the neighbourhood of Mangli (Mangali), a small deserted village at the northern extremity of the Wardha Gondwana basin, about fifty miles south of the town of Nagpur and thirty-five miles northwest of Chanda, some quarries have long existed from which a very fine, red and yellow sandstone is obtained and employed in building, chiefly for ornamental purposes. The stone is described as similar to that of Silewara and other typical exposures of the Kamthi stage near Nagpur, and the associated coarser sandstones of Mangli differ in no way from the ordinary Kamthi grits. For these reasons, the Mangli beds were originally grouped with the Kamthis, but there is much in favour of Dr. Cotter 's view that they should be included where W. T. Blanford suggested they should be placed, namely, within the Panchet series; to the lower portion of this formation, therefore, they are assigned.

It was the quarries of Mangli which furnished to the Rev. Mr. Hislop the first labyrinthodont amphibian fossil discovered in India, *Brachyops laticeps*;[2] the horizon from which the specimen was obtained has been estimated as occurring at 600-700 feet above the base of the formation and is probably the equivalent of the conglomerate of the Panchets found at Deoli in the Raniganj coalfield.

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[1] Identified by Dr. E. I. White; *vide Mem.*, LXI, 59 (1932).

[2] *Q.J.G.S.* Vol. X, 472 (1854); *Ibid.*, XI, 37 (1855).

[3] W. H. Hughes. *Mem.*, XIII, 71 (1877); C. S. Fox. *Ibid.* LVIII, 158 (1931).

The Mangli quarries have also yielded a species of [*Cyzicus*] *Estheria* and a few plant remains too poorly preserved for reliable determination, one being the stem of a fern.[1] The species of *Cyzicus* or *Estheria* was named *Estheria mangaliensis* by Rupert Jones;[2] a smaller variety of this form closely resembles the poorly preserved *Cyzicus* found in the Panchet series of Bengal and may be identical. *Brachyops* is supposed to be closely allied to the genus *Micropholis*, which is characteristic of the *Procolophon* zone (Lower Trias) of the Beaufort Beds of South Africa,[3] and to *Bothricaps australis* and *B. major* of the Australian Newcastle stage (uppermost Permian).

Equivalents of the Mangli beds have been recognised around Kawarsa and Panwat, about sixteen miles west of the town of Chanda, and also on Balar Hill between Panwat and Wun. From the former of these exposures have been obtained: [*Cyzicus*] *Estheria mangaliensis*, *Phyllotheca indica*, *Glossopteris indica*, *G. browniana*, and fragments of *Schizoneura*.

PARSORA STAGE OF SOUTHERN REWAH.

Around the village of Parsora in southern Rewah are some supra-Barakar beds whose precise age is disputed but which may be referable to some part of the Panchet series. The Barakars are here succeeded by the Pali beds which contain Damuda plant remains and are regarded as equivalent to the Kamthi stage. From Pali to Parsora there is a steady northward dip bringing in a younger formation with a younger flora. The junction between the Pali and Parsora stages is masked, and the apparent lithological similarity between the two is attributed by Fox to prolonged exposure above ground-water level, under plateau conditions, of the gently-inclined strata, whereby the rocks have been coloured indiscriminately by ferric oxide.[4]

The Parsora stage consists of extremely fine-grained, dark red, ferruginous shales, associated with silico-felspathic sandstones of a yellowish and brownish grey colour and highly-coloured sandstones mottled yellow and red. The sandstones are described as of Mahadeva aspect, but from the shales have been collected.[5]

FILICALES—

Thinnfeldia (*Dicroidium*) *hughesi* (Feistm.) ("*Danæopsis hughesi*", now referred to the provisional genus of *Thinnfeldia*),
 ,, ,, *odontopteroides* Morr. (found as high up as the Lower Jurassic in Australia).
 ,, *sahnii* Sew, (probably identical with some of the specimens named *T. odontopteroides* (Morr.)[6] or *T.* (*Dicroidium*) *feistmanteli* Johnst.[7]),
 ,, sp. (perhaps identical with the following species),
"*Asplenium* (*Alethopteris*) *whitbyense*" (Goöp.) Heer ? (*Cladophlebis denticulata*; may well be a *Thinnfeldia*).

CORDAITALES—

? *Cordaites* (*Noeggerathiopsis*) *hislopi Bunb.*,[8]

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[1] Some of these have been referred by one authority to the conifer, *Palissya* (Feistmantel) *Rec.*, X, 26 (1877), and by another possibly to the lycopod genus, *Knorria* (*Man.*, 2nd Edi. 170 (1893).

[2] *Pal. Soc.*, Foss. Estheriæ, p. 78 (1862).

[3] G. de P. Cotter. *Rec.*, XLVIII, 29 (1917).

[4] *Mem.*, LVIII, 190 (1931).

[5] The recorded presence of *Neocalamites* is doubtful.

[6] *Rec.*, LXVI, 236 (1932).

[7] *Thinnfeldia sahnii* comes from Chicharia, six miles north of Parsora, and possibly from a higher horizon.

[8] G. de P. Cotter notes the possible identity of these broken leaves with a supposed *Cordaites* from the Rhætic of Tonkin, which Seward suggests may be the same as *Phœnicopsis elongatus* from the Stormberg series of South Africa. *Rec.*, XLVIII, 30 (1917).

Fox, in his recent re-survey, was unable to confirm the presence of *Cordaites* in the Parsora beds.[1] *Thinnfeldia odontopteroides* and *T.* ("*Danaeopsis*") *hughesi* are characteristic of the Trias and Rhætic; the former is a well-known species found in South Africa (Molteno Beds), Australia, South America and parts of Europe, while the latter occurs in the uppermost part of the Beaufort Beds of South Africa and in the Rhætic of Tonkin and China.[2] The so-called "*Asplenium whitbyense*" is a doubtful Raniganj form and is more characteristic of the Jabalpur and Umia beds of the Upper Gondwana; the supposed specimen from the Parsora beds is quite possibly a *Thinnfeldia.*[3] In the opinion of Seward, who assumed the presence of *Cordaites hislopi* to be correct, it is in the highest degree probable that the Parsora flora is not younger than Lower Trias, its most abundant species, in fact, pointing rather to the late Permian of the northern hemisphere.[4] The red coloration in the Parsora beds is regarded by Fox as a secondary feature and therefore no clue to climatic conditions.

LOWER GONDWANAS OF THE GARO HILLS, ASSAM.

An interesting and important discovery by Sir Cyril Fox proves that Lower Gondwana rocks are present in the Garo Hills area of the Shillong Plateau. At Singrimari, some carbonaceous shales, with which are associated lenticles of coal, sandstone and grit, have yielded specimens of *Vertebraria indica*. The beds, which were formerly regarded as Cretaceous, have been assigned by Fox to the Barakar as a result of the analysis of the coal, which shows a proportion of volatile matter to fixed carbon of 17 to 40. The Singrimari measures dip gently westwards under the Jinjaran river alluvium, and are cut by dolerite dykes; they contain no workable seams of coal. The dykes are lithologically identical with the dolerites and basaltic lavas and dykes of the Rajmahal and Deccan Trap; similar dykes are found throughout the gneissic area of the Garo Hills.[5]

B. UPPER GONDWANA.

General relationships.—The break between the Lower and Upper Gondwana is considered to occur above the change from Palæozoic to Mesozoic times. The Upper Gondwanas as a whole differ little in lithology from the Lower division but show greater local variation. In some places clays and shales are more predominant and pebble beds less conspicuous, in other places the beds consist principally of coarse sandstone, grit and conglomerate. The sandstones are apt to decompose readily into loose sand which covers much of the surface of the country and greatly conceals rock outcrops. Seams of coal are fewer, thinner and more irregular. Workable seams are known in Cutch and the Narbada valley (Lameta Ghat and Jubbulpore) as well as in beds corresponding in age to part of the Upper Gondwana in Burma, but are of no great economic importance;[6] thin rare seams are also found in the Satpura region and in the Chikiala beds of the Godavari valley. From the desert climate of the Panchet-Parsora period, there was a return to more humid conditions or at any rate to an alternation of wet and dry seasons, signalised by the appearance of a new flora characterised by the presence of cycads, the predominating form of which was *Ptilophyllum acutifolium*. It has been suggested that the undecomposed condition of the felspar grains in the

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[1] *Mem.*, LVIII, 190 (1931).

[2] G. de P. Cotter. *Rec.*, XLVIII, 30 (1917); B. Sahni. *Proc. 8th Ind. Sci. Congr. CLXII-CLXIII* (1921).

[3] A. C. Seward. *Rec.*, LXVI, 237 (1932).

[4] *Ibid.*, 242; *vide* also B. Sahni. *Proc. 13th Ind. Sci. Congr.*, p. 246 (1926).

[5] *Gen. Rep.*, *Rec.*, LXVIII, 76 (1934).

[6] C. S. Fox. *Mem.*, LVII, 27 (1931).

Panchet sandstones implies a return to cold conditions, but it is not certain whether such a deduction follows the premise. The supersession of the meagre Panchet flora by the copious Rajmahal assemblage would, at any rate, suggest a change from rather barren to more fertile conditions ; at the same time, the Mahadevas, which are presumed to correspond to the Rajmahals of Bengal, show no signs of fertile conditions and are more barren even than the Panchets, from which it may be inferred that the climate in the northeastern corner of the Peninsula was as different from that further west as it is today. The change from a mainly Palæozoic to a mainly Mesozoic vegetation took place in India during the Triassic period, corresponding closely to the similar change which during Triassic-Rhætic times was effected in Europe and other parts of the world. The Upper Gondwana flora as a whole shows a close general resemblance to the Jurassic and early Cretaceous, not only of other parts of Gondwanaland but also of the northern hemisphere, and maintains a striking uniformity of character throughout with only comparatively slight changes to mark the lapse of time.

In places, the Upper Gondwanas are seen to overlap the Lower. In the Satpura region, the Jabalpur beds overlap not only the Mahadevas but also the Bijoris, southwards, and ultimately, in Jamgarh Hill, rest upon the Motur stage.[1]

As in the case of the Lower division, the study of the Upper Gondwana flora has suffered unavoidably from synonymy, due to the fragmentary and disconnected character of the plant remains. Little by little this is being corrected in the light of fresh discovery. Not only are the various leaves, stems, flowers and fruits, receiving classificatory readjustment but the inter-relationships of some of these plant parts are becoming clarified. The fructification, *Williamsonia*, for instance is now known to have been carried on the stem known as *Bucklandia*, perhaps subtended by the bracts known as *Cycadolepis pilosa*, and there is excellent reason to conclude that the leaves of this plant were those which have been designated *Ptilophyllum*. Similarly, the flowers known as *Williamsoniella* probably belong to the same plant which bore the fronds named by Brongniart *Tæniopteris vittata*.

MAHADEVA SERIES.

MAHADEO HILLS OR SATPURA REGION.

Distribution, structure and sub-division.—Above the beds so far considered, there ensues in the region of the Mahadeo hills, south of the Narbada valley, a succession of beds in which fossils are rarely found and which, by reason of the unconformity at their base, have been classified as the lower part of the Upper Gondwana and referred to under the name of Mahadeva.[2] The name first applied to the sandstones of the Pachmarhi hills[3], was subsequently extended to comprise all the beds of the Mahadeo basin above the Damudas of the lower Denwa valley except those of the Jabalpur series, the Rajmahal series of other localities being unrepresented in its trappean and plant-bearing facies. With a maximum width in the centre of about twenty-five miles the outcrop of this series stretches E.N.E.-W.S.W. for over a hundred miles, the maximum thickness of the beds not exceeding 5,000 feet.[1] The fact that the Mahadevas lie upon Damuda rocks would presuppose an unconformity representing at least the Panchet series, and evidence of such discordance is duly forthcoming.

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[1] *Gen. Rep.*, *Rec.*, LXVII, 67 (1933).

[2] It has been suggested that the stages constituting this series should be included in the Lower Gondwana with the Panchet "stage" under the title of the Panchet series but further work since the suggestion was made has shown that the unconformity at the base of the beds under consideration is greater than any of the minor discordances noted at other horizons in the system, and that there is little if any break at their upper boundary.

[3] T. Oldham. *J.A.S.B.*, XXV, 252 (1856) ; J. G. Medlicott. *Mem.*, II, 183-267 (1860).

The beds of this Gondwana basin have been warped into one or two broad synclinal and anticlinal flexures but, disregarding these, there is a prevalent dip northwards, accompanied by a progressive decrease in age in the same direction, the oldest beds, generally speaking, being exposed along the south. It has been suggested that the Narbada valley marks a line of major fracture, and it seems highly probable that this dislocation formed the approximate northern boundary of this basin, which has every appearance of having been that of a lake. The present-day riverine tracts are, of course, occupied by a broad alluvial tract which conceals not only the fault but also the Gondwana deposits fringing it to the south and, if there ever were any, similar deposits along its northern side. Both in the neighbourhood of the Narbada plain and further south, the Mahadevas are cut by important strike faults directed E.N.E.-W.S.W. Many other minor faults are occupied by dykes of Deccan Trap orientated in the same general direction.

The Mahadeva series of the Mahadeo hills is divisible into three stages of deposition, whose inter-relationship may be expressed in a general way as follows :[2]

3. Bagra stage.
2. Denwa stage.
1. Pachmarhi stage.

This order of sequence, however, is not strictly and completely chronological. The Pachmarhis, for instance, although in a general way forming the basal portion of the series, pass laterally eastwards into beds identical with the Denwa rocks and are actually underlain by sediments indistinguishable from the latter ; the two in this way merge into one another by the elimination of the typical members of each. The Bagras also are but a conglomeratic variant of the higher portion of the Denwa rocks into which they pass laterally. The Mahadeva is best regarded

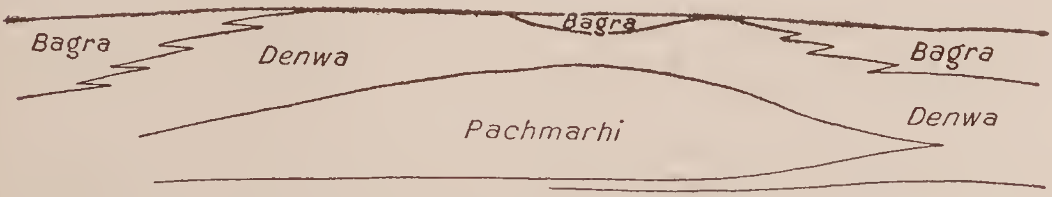

Fig. 17. Bagras, Denwas and Pachmarhis merging into one another.

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[1] The estimate of "at east 10,000 feet", (Man., 2nd Edit., 172) was made under the mistaken impression that the thickness of the Pachmarhi sandstones was 8,000 feet.

[2] C. S. Fox. *Mem.*, LVIII, 113 (1931).

as a single stratigraphical unit, whose stages are but three different facies and are not everywhere superposed the one over the other.[1] The relationship is expressed pictorially in Fugire 17, which shows the Pachmarhi sandstones as an enormous isolated lens of arenaceous deposits between either the Denwa clays or Bagra conglomerates above and the Bijoris below :

Pachmarhi stage.—The typical Pachmarhi beds, named after the well-known hill-station, are singularly uniform in character, consisting of coarse, white, usually soft sandstones, separated from one another by layers of white, sub-angular quartz pebbles. The coarser layers in the beds include angular chips of felspar but not to the extent seen in the Motur rocks. According to Dr. Crookshank current-bedding is universal and generally takes the form of curved partings joining successive pebble beds.[2] As a rule, the stratification is obscured by such oblique lamination, and the different members of the group exhibit great irregularity in superposition and often overlap each other. Both partings and bedding planes, over the greater part of the Pachmarhi area, are characterised by iron infiltrations which weather out in the form of ferruginous slabs, often of fantastic shape. Fragments of these ferruginous bands are often found scattered in quantities over the surface of the ground and serve to distinguish the outcrop of the Pachmarhis from that of other Gondwana rocks. Sometimes the impregnations of iron are confined to pipes or nodules. As already pointed out, similar ferruginous depositions are typical of the Kamthi-rocks.

In the typical Pachmarhi area of the Mahadeva range, beds of clay are almost unknown, but east of the Denwa river they begin to appear among the sandstones, and further east the Pachmarhis merge insensibly into the Denwa beds. Throughout a large section, the base of the Pachmarhis consists of a bed of red clay.

The maximum thickness of the Pachmarhi beds is at least 3,000 feet, but the beds dwindle in places to about 500 feet. The Pachmarhi sediments were deposited in water which was shallow but, judging from the absence of ripple-marking, not so shallow as that in which the Bijoris accumulated. The Pachmarhi sediments would appear to represent a large sand-bank deposited most probably in a lake or less likely along the course of a large river. From the absence of jasper pebbles in the conglomeratic beds, and from the dip of the current-bedding, Crookshank deduces that the Pachmarhi sediments were derived, not from the north where jasperoid rocks must have abounded, but from the south.

The Pachmarhi sandstones occupy high ranges of hills and often weather into vertical scarps of great height ; these conspicuous cliffs contrast strongly with the black precipices of the Deccan traps and the rounded irregular masses of the more granitoid metamorphic rocks. The Pachmarhi beds give rise to an exceptionally barren soil, on which euphorbias and a few low shrubs are usually the only forms of vegetation seen. The peak of Burimai, several miles south of the main Mahadeo range, is believed to be an outlier of Pachmarhi sandstone, towering in a vertical cliff 200 feet above the softer Bijori rocks.

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[1] In view of the great thickness of the Mahadeva series, and in an attempt at a more closely chronological or taxial scheme of subdivision, Crookshank has modified the above arrangement by prolonging the line dividing the typical Pachmarhi sandstone from the typical Denwas into areas east and west, keeping as near as possible to the same geological horizon. In this way there results a Pachmarhi stage including all those rocks which on field evidence seem to be contemporaneous with the typical Pachmarhis of the main Mahadeva range, even though lithologically they resemble more closely the Denwas. Apparently it was found impracticable to do the same with the junction between the Denwa and Bagra, and the latter is treated by Crookshank as a conglomeratic facies of the upper Denwa beds. The mapping of such ill-defined stages is necessarily of an arbitrary kind.

[2] *Mem.*, LXVI, 229 (1936).

No fossils are recorded from the Pachmarhi stage, but fragmentary plant remains have been found in beds which, although belonging to the Denwa facies, appear to lie on a stratigraphical level with Pachmarhi horizons; they are described as giving the impression of being closer to the Jabalpur flora than to the Bijori.

Denwa stage.—The typical Pachmarhi beds dip northwards at a low angle beneath the Denwa beds. The latter are best exposed along the western course of the Denwa river and in the valley of the Dudhi, north of the Pachmarhi plateau, and present, as a whole, a marked contrast to the massive Pachmarhi sandstones on which they lie with apparent conformity, and into which they pass in some places. They are composed principally of soft, variegated clays, thick beds of which are interstratified with discontinuous and subordinate bands of white sandstone; locally the sandstones are conglomeratic. The absence of white clays and carbonaceous rocks distinguishes these from younger Gondwana beds, while the rarity of fossils contrasts them with the Lower Gondwanas. Occasional erratic boulders have been noted in the Denwa clays near Chaugan; none of them shows ice-scratching but, as Crookshank suggests, it is possible for them to have been brought down by ice formed during the winter in any neighbouring mountain region.[1] That these erratics may have been derived from the Talchir, a stage which underlies the Bagra-Denwa beds in the immediate neighbourhood, seems also possible; such erratics might, presumably, have rolled down from higher Talchir ground into the Bagra-Denwa waters after losing any ice-grooving they may have originally possessed.

The Denwa clays are always calcareous and often contain numerous calcite nodules. Their colour varies between green, red and buff, red being most characteristic. Buff clays are common, especially along the boundary with the Pachmarhis; mottled red and white, or green and white, colouring is also frequently seen. The Denwa sandstones are less massive and much softer than the typical Pachmarhi or Jabalpur sandstones, and generally much more conglomeratic than the Bijori. The frequency of red jasper among the pebbles in the Denwa beds, in contrast to their rarity in the Bijori conglomerates and their absence in the Pachmarhis, points to the Narbada valley region to the north as the origin of the Denwa sediments.[2] The Denwa beds have yielded *Mastodonsaurus indicus*[3] a labyrinthodont very closely allied to *M. gigenteus* Jäger from the Keuper of Würtemburg, and some obscure plant remains including leaf impressions resembling *Phœnicopsis* and the trunk of a tree. *Mastodonsaurus* in Europe ranges from the Upper Muschelkalk to the Keuper, and is found in the Hawkesbury Beds of Australia (Middle Trias).

Bagra "stage".—The Bagra stage, named after a hill fort built upon it where the river Tawa cuts its way through a spur of the Mahadeo hills southeast of Hoshangabad, is restricted to the northern margin of the Mahadeva Gondwana basin. In the west, it appears to overlie the Denwa beds, overlapping them or the Pachmarhi sandstones with marked unconformity; eastwards, the upper beds of the Denwa have been shown to pass laterally into the red banks of conglomerate which form the principal constituent of the Bagra beds. The Bagra facies is very irregular in composition and is more calcareous than the Denwa. Although largely composed of conglomerates, which are often coarse, it includes frequent bands of calcareous sand, variegated clay, limestone and dolomite ; the dolomites are probably accounted for by the presence among the neighbouring metamorphic rocks of siliceous dolomitic marble.

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[1] *Mem.*, LXVI, 271 (1936).

[2] *Mem.*, LXVI, 234-236 (1936).

[3] *Pal. Ind.*, Ser. IV, Pt. 5, 30 (1885); the specific name is given in the British Museum Catalogue of Fossil Reptilia and Amphibia, Pt. IV, p. 145 (1885). The supposed *Parasuchus* from the Denwas proved to be a labyrinthodont.

The coarser constituents of the conglomerates are all rounded and vary in size from small pebbles to boulders as large as a man's head ; they are cemented by a matrix which is usually argillaceous, sometimes calcareous, and frequently of a deep red colour. The pebbles and bould rs, which have been derived from both local and distant sources, are of many kinds, including quartzites, banded jaspers and jasperoid conglomerate and other examples of the rocks exposed along the northern edge of this Gondwana basin. The quartzites closely resemble some of the Vindhyan examples exposed on the north side of the Narbada near Hoshangabad ; the jaspers in all probability come from the Bijawar rocks and the jasperoid conglomerate from the Kaimurs, both mainly exposed to the north of the Narbada. The conglomerates are occasionally seamed with beds of coloured clay.

Near Mohpani, the conglomerates directly overlie the coal-bearing Damuda and similar relationships occur in the vicinity of Bagra, where coal has also been found.[1] Not infrequently, the Bagra beds are seen lying directly upon metamorphic rocks and, in one section, on beds very like the banded hæmatite quartzites of the Iron Ore series. In places, they rest on the Talchirs, in others on the Pachmarhi sandstones. This overlap and irregularity confirms the conclusion that the Bagra conglomerates are coastal deposits and merely a shore-line facies of the Denwas.

The Denwa-Bagra succession increases in thickness from zero in the east to over 1,000 feet in the Nimbugarh scarps, and to 1,700 feet near Thana. To the east and west, it is followed by the Jabalpur series, the junction with which is commonly an unconformity ; in the south, however, in the deeper parts of the basin there is no sign of discordance and the two formations are said to be imbedded with one another in some places. The only organic remains found in the Bagras are some gastropod casts from immediately above the contact with the metamorphics, and some fossil wood. The possibility that the Mahadevas stride the Rhætic and Upper Trias rather than the Rhætic and Lias connot be entirely ignored, especially if the Denwas are correlated with the Maleris of the Godavari valley and the Tikis of Rewah, as Dr. Cotter suggested ; such an alternative view would probably necessitate the rejection of the claim that the Denwas in places pass up into the Jabalpurs, and the attaching of greater importance to the unconformity and marked overlap which the Jabalpurs elsewhere show towards the Denwas.

GODAVARI VALLEY.

With the Pachmarhis, especially when these beds assume a Denwa facies have been correlated two other formations, one in the Wardha-Godavari area known as the Maleri stage, and the other in the southern Rewah basin, the Tiki stage. The Maleri stage which, until recently, was associated, terminologically with the

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[1] C. S. Fox. *Mem.*, LVIII, 29 (1931).

Kota, is exposed in the Wardha-Penganga valley and has been named after a village within the State of Hyderabad and some thirty-two miles north-west of Sironcha.[1] Sir Cyril Fox supports the revival by Dr. Cotter of the earlier views of Dr. King that there is a stratigraphical and palæontological break between the Maleri and Kota formations, and that the former is older than the latter ; at the same time there are reasons for retaining the Maleris—as well as the Kotas—in the Upper division of the Gondwana system as defined in this work.[2]

The Maleri beds, which are slightly but distinctly unconformable to the subjacent Kamthis, consist essentially of bright red clays, interbedded with soft light-coloured and open-textured sandstones subordinate in thickness to the clays ; some of the more compact sandstones enclose green or red clay balls. In places, there is marked overlap of the Maleris on to the lower portion of the Kamthi stage. In the southeast part of the outcrop, the bottom beds are yellow and red friable sandstones with purple sandy clay bands ; these gradually change upwards into dirtier, slightly calcareous beds with clay balls, the red clays ultimately making their appearance with gradually thinning bands of the calcareous sandstone. Sometimes the lower members of this sequence are missing and the red clays lie directly and unconformably on the gravelly sandstones of the Kamthis. According to Aiyengar, the top of the stage in the type area is composed of about 20 feet of sandstones, some of them current-bedded, with one coarse and rubbly layer containing reptilian remains.[3] A thickness of over 2,000 feet is estimated by King in one section, but this is thought to be an exceptionally high figure ; there is probably great variation in thickness of the stage. The Maleri beds are said to show a well-marked lithological resemblance to the Panchets.

Fossils are found on the surface of the ground, derived chiefly from the red clays, coprolites being much the most abundant and strewn in large numbers about the fields. In addition, three species of *Ceratodus*—*C. hunterianus* Oldh., *C. hislopianus* Oldh. and *C. virapa* Oldh.–as well as a species each of two genera of reptiles, *Hyperodapedon* and *Parasuchus*, *viz.*, *Hyperodapedon huxleyi* Lyd., and *Parasuchus hislopi* Lyd., have been recognised.[4] Other remains are labyrinthodont cranial bones with sculpturing so similar to that of specimens found at Tiki (*Metoposaurus*) that it seems probable that they are fragments of the same species.[5] Pieces of coniferous wood have been collected from these beds, including *Mesembrioxylon malerianum* Sahni and *Dadoxylon* (*Araucarioxylon*) sp. There is little doubt that the Maleri beds are the equivalents of the Tiki beds (*q.v.*).

SOUTHERN REWAH AND NORTHERN SARGUJA.

A large tract of rocks in southern Rewah and northern Sarguja, traversed by tributaries of the Son and stretching westwards into the district of Jubbulpore in the direction of the Satpura region, is shown on the latest 32-mile geological map as Upper Gondwana beds, which succeed the Pali beds of Raniganj age. This tract, however, includes the Parsora stage which, as already stated, may represent the lower horizons of the Panchet series and so belong to the Lower

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[1] The name of this village was originally recorded as Maleri but figures on more recent maps as Marweli.

[2] *Mem.*, LVIII, 157 (1931).

[3] *Rec.* 71, 402, p. 403 (1936).

[4] L. C. Miall. *Pal. Ind.*, Ser. IV, vol. 1, Pt. 2, 9-17 (1878) ; R. Lydekker. *Ibid.*, Pt. 5 (1885).

[5] G. de. P. Cotter. *Rec.*, XLVIII, 26 (1917).

Gondwana. It is quite possible that the higher portions of the Panchet are present in places. The highest Gondwanas of this tract have been referred to the Jabalpur series.

Forty miles northeast of Parsora are the Tiki beds ; the inter-relationship between the two stages is not clear but the balance of evidence seems to favour the view that the Tiki is younger than the Parsora. The Tiki beds are of typical Maleri aspect and include sandstone with clay balls ; at the top they include about 15 feet of ferruginous sandstone overlying some 10 feet of fine-grained sandstone, some of which is current-bedded and contains partly carbonised and partly calcified fossil wood.[1] From the Tiki stage the following fossils have been collected : a jaw fragment and several pieces of cranial bones of a labyrinthodont shewing a close relationship to *Metoposaurus* ;[2] some jaw remains of a species of *Pachygonia*, another labyrinthodont, probably identical with the Panchet *P. incurvata* Huxl.[3], the Maleri reptile, *Hyperodapedon huxleyi* Lyd., a species of the crocodilian, *Belodon* ; the dinosaur, *Massospondylus*, a Karroo genus ;[4] and a species of *Unio*.[5]

There seems little doubt that the Maleri and Tiki beds are more or less equivalent and the fauna, therefore, may be considered collectively.[6] The labyrinthodonts, first appeared in the Carboniferous and, there is some reason to believe, died out in the Rhætic. *Metoposaurus* is a genus ranging from upper Muschelkalk to Keuper. The genus, *Hyperodapedon*, is found in the Keuper of Europe. *Belodon* has Triassic affinities and *Parasuchus* belongs to a Triassic sub-order. The dipnoan, *Ceratodus*, in South Africa ranges from the *Cygnognathus* zone of the Upper Beaufort Beds (Middle Trias) to the Red Beds of the Stormberg series (uppermost Trias) and is found in the Trias and Jurassic of Europe as well as in the Upper Jurassic of Victoria in Australia. The genus *Massospondylus* is also found in the Red Beds of South Africa. *Unio* is rare below the Oolite but is found in the Hawkesbury beds of Australia and doubtfully in the American Trias.[7]

The above analysis of the fauna by Dr. Cotter constrained him to group the Maleris and Tikis, as well as the Denwas, with the Panchet series and therefore members of the Lower Gondwana division, and as " Upper Triassic, possibly

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[1] N. K. N. Aiyengar. *Rec.*, 71, 405 (1936).

[2] The fragment of the lower jaw was mistakenly described by Lydekker as part of the maxilla.

[3] R. Lydekker. *Rec.* XV, 26 (1882).

[4] At first doubtfully identified as *Thecodontosaurus*. R. Lydekker. *Pal. Ind.*, Ser. IV, Vol. I, Pt. 5, 28-29 (1885).

[5] M. R. Sahni and A. P. Tewari have since described from the Tiki beds a Triassic unionid fauna (form collections by Messrs. N. K. N. Aiyengar and C. Nageswar Rao) ;

Tikkia corrugata Sahni and Tewari,
T. navis Sahni and Tewari,
T. compressa Sahni and Tewari,
T. subangulata Sahni and Tewari.

(Current Science, vol. 24, No. 6, June 1955 ; *Rec.*, LXXXVII, pt. 2 (1953).)

[6] *Ptilophyllum acutifolium*, *Tæniopteris* (*Angiopteridium*) *spatulata*, *Palssya conferta* and *P.*(?) *indica* are recorded as having been collected from " Chirakunt "(Charakota, southwest of Jangaon), a village which on King's map is marked within the Maleri boundary though not much more than a mile from the adjoining Kotas. The plant remains are almost certainly Kota, and the beds around Charakota, although appearing on the map as Maleri, are alluded to in his text as Kota. A slight adjustment of King's Maleri-Kota boundary is probably needed. Additional collections of reptile remains by Mr. Aiyengar are under examination by the Baron von Huene of Tübingen.

[7] C. A. Süssmilch. "Geology of New South Wales", 3rd Edit., 113 (1922).

Rhætic," in age. The presence of the *Pachygonia*, especially if identical with the Panchet species, is interesting and may be a survival if a Rhætic age be assigned to the Tiki-Maleri beds. In addition to the organic remains already mentioned, some well-preserved coniferous wood from the Tiki beds has been shown to belong to *Mesembrioxylon* (*Malerianum* Sahni), a genus which, so far as present records go, ranges from Jurassic to Recent.[1] Sir Cyril Fox allotted the three stages, Maleri, Tiki, and Denwa to the Upper Gondwana, where they were originally placed; he would at the same time agree with Dr. King in dissociating them from the Kota beds which both authorities would place above the Maleris. Provisionally, the Tiki and Maleri beds may be assigned to the Rhætic, but the possibility of their belonging to the Upper—or Upper and Middle—Trias must not be overlooked.[2]

MAHANADI VALLEY.

In the Mahanadi valley, the Upper Gondwanas of the Talcher coalfield are thought to be represented by about 800 feet of grits and conglomerates, which are ferruginous and contain beds of jaspery ironstone like those seen in the Mahadevas of the Mahadeo hills. They lie upon beds which have been referred to the Kamthis and which exhibit a somewhat greater degree of disturbance. The presumed Mahadeva beds are the youngest exposed in this area; they have been compared with the Athgarh Sandstone found nearer the coast, and may be approximately of the same age.

In the Hingir coalfield, northwest of the Talcher area, the Barakars are overlain by the Hingir beds which are believed to be the equivalents of the Kamthis or Raniganj. It is doubtful whether any Upper Gondwana rocks are exposed in this area.

Further northwest, between Korba and Dharmjaygarh is an expanse of supra Barakar sandstones which are either Hingirs or Mahadevas.

North of the last-mentioned area, a small patch of doubtful Mahadeva beds has been noted in Pilka Hill in the Bisrampur coalfield, situated in the wide lowlands of central Sarguja. No fossils have been found in these beds.

DAMODAR VALLEY AND COUNTRY IN A LINE TO THE WEST.

Tatapani.—The Mahadeva beds of the Tatapani coalfield form the eastern termination of the large Upper Gondwana tract which covers so much of southern Rewah and northern Sarguja. Throughout a large section of their boundary they succeed the Panchet series, but in various places they are in contact with the Raniganj or even the Barakar, nor is this junction always a faulted one. In spite of an apparent conformity in dip between the Mahadevas and the underlying Lower Gondwana beds, there are good grounds for suspecting an overlap of appreciable magnitude. The Mahadevas, consisting mostly of thick beds of ferruginous, gritty sandstone, generally current-bedded and with the characteristic ferruginous partings, occupy a large proportion of the field and give rise to bold escarpments, the steepness of which is due to extensive jointing.[1] Some 800 feet of these beds, which are the youngest sedimentaries of the area, are present, and are traversed here and there by dykes of Deccan Trap; in some places the trap has pushed its way in sheets between the Mahadevas and the Lower Gondwanas.

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[1] A. C. Seward. "Fossil Plants", IV, 173 (1919). *Pal. Ind.*, New Ser., XI, Pt. 2, p. 63 (1931), Another species, *M. godaverianum* Sahni, was obtained either from the Maleri or from the Kota beds, the locality being "Bogapalmila" (*Ibid.*, p. 59). A species of *Dadoxylon*, *D.* (*Araucarioxylon*) sp., comes from the Tiki beds between Mirwar and Chakwa (*Ibid.*, p. 71).

[2] C. S. Fox agrees with Cotter attributing a Rhætic to Keuper age to the Maleri stage, and a Lower Oolitic to Liassic age to the Kota. The difference between the two observers lies chiefly in the level at which the boundary between the Lower and Upper Gondwana is to be drawn. *Mem.* LVIII, 92, 231-232, etc. (1931).

Hutar.—In Hutar, in the Palamau district, Dunn estimates the thickness of the Mahadevas to be much less than 1,000 feet.[2] Both Panchet and Raniganj are absent in this field and Mahadevas, which build up the higher hills, rest upon Barakar beds, with no visible discordance. The more luxuriant vegetation to which the Mahadeva rocks give rise, as compared with the more parched country of the Lower Gondwanas, is well illustrated in Hutar as it is in Tatapani. Griesbach explains this as due to the fact that, on decomposition, the Mahadevas of this area produce a heavy clay soil capable of supporting perennial streams, whereas the Barakars are remarkable for the dryness of their soil which is so sandy that the rivers flowing over it rarely contain any appreciable water during the dry season. While the Mahadeva country of Hutar is characterised by fresh *sal* and mixed forest, with ferns, arums, grasses and mosses, the black, scorched and dusty jungles of the Barakars and Talchirs can only boast of dry thorn bush and species of mimosa trees.

The Daltonganj (Palamau) coalfield, north of Hutar, has nothing younger than Barakar beds.

Aurunga.—The Mahadeva rocks of the Aurunga field, in the Palamau district, occur in small isolated outliers. In the eastern portion of the area, Raniganj and Panchet beds intervene between the Barakars below and the so-called Mahadevas above; in the western part of Aurunga, as in the Hutar field, the Mahadeva beds lie unconformably, though not visibly so, upon the Barakars. In the Aurunga area, the maximum thickness of the Mahadeva series remaining undenuded has been estimated at 1,000 feet, the beds occupying the few hills with scarped sides in the flat or gently rolling terrain. The rocks consist chiefly of ferruginous sandstone with extremely sparse strings of iron-stained quartz pebbles, and occasional thin partings of dense red clay; there are also white, friable grits, from which the iron has been segregated into dense ferruginous plates. As in the neighbouring Hutar field, conglomerates are scarce.

Karanpura.—Still proceeding eastwards, we find that overlying the Panchets and forming the great central hill masses of the Karanpura coalfield in the district of Hazaribagh are some massive sandstones or grits, varying in colour from bright red to yellow and white, assigned by Jowett to the Mahadeva series. The sandstones are highly current-bedded and characterised by layers of sub-angular, iron-stained pebbles; locally the pebbles are sufficiently numerous to constitute a conglomerate. Flaggy beds of finer texture are rare, and the nearest approach to a shale is a hard, fine-grained, micaceous sandy rock; carbonaceous material is absent. The steadiest dips are southerly and westerly, but the beds are not far from horizontal, and give rise to striking escarpments with screes of large cuboidal blocks.

The three largest exposures are faulted along their southern boundaries. In most places these sandstones appear to rest conformably upon the Panchets, but an overlap of the older by the younger rocks has been proved by Dr. Jowett.

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[1] C. L. Griesbach. *Mem.* XV, pt. 2-20, (1880). The reported discovery of *Alethopteris* and *Glossopteris* is extremely doubtful, the remains are more likely to have come from Panchet beds.

[2] In C. S. Fox., *Mem.* LIX, 154 (1934).

The hills of Panchet rocks are capped by these supra-Panchet beds, but in one hill the latter lie directly upon Barakar rocks. In a few cases, the discordant nature of the lower boundary is distinctly visible, and in one place the supra-Panchets rest on a considerably disturbed sequence of Panchet and Raniganj beds, which must have undergone local folding, faulting and denudation before the deposition of the younger beds.[1]

Bokaro.—Supra-Panchets or supposed Mahadeva beds are again recognised in the Bokaro field further east, and no doubt at one time they as well as the underlying Panchets stretched continuously across the Jharia field from Raniganj to Bokaro and thence westwards to Karanpura, Aurunga and beyond. Nothing remains of them in the Jharia area. In Bokaro they form the summit of Lugu Hill, lying upon Panchet beds, the junction with which is concealed by detritus. The beds, which consist of coarse conglomerates, grits and sandstones, highly impregnated with iron, and generally reddish in colour, resemble in every way similar beds capping Panchet Hill in the Raniganj coalfield further east.

Neither the Supra-Panchets nor the Panchets are found in the Ramgarh field or the Jharia field.

Raniganj.—Along the southern edge of the Raniganj coalfield, a series of coarse pebbly sandstones with subordinate dark-red clays are seen resting at intervals on the Upper Panchet strata. Mr. Gee describes the beds as covering an area of about four square miles and constituting the higher portions of Panchet, Gorangi and Biharinath Hills. The junction with the underlying Panchets is believed to be an unconformable one, but the slopes of these hills are so covered with small trees and undergrowth, and strewn with so many boulders and other detritus that the boundary is rarely observable. The thickness of the supra-Panchet beds on Panchet and Biharinath Hills is at least 1,000 and may be as much as, 1,200 feet.[2] The beds include yellowish grey to red, ferruginous, felspathic sandstones, most of them comparatively soft in texture and becoming friable on weathering. Several of the sandstones contain numerous rounded or partially rounded pebbles consisting largely of white or pinkish quartzite; such conglomeratic sandstones are well exposed on the summits of Panchet and Biharinath, where they are practically horizontal. Associated with these strata are bands of white felspathic sandstone of medium texture, and of red and brownish clay, often shaly and micaceous. The clays have yielded a few imperfect and unidentifiable remains of plant stems and leaves.[3] It is quite probable that these supra-Panchet rocks are the equivalents of the Dubrajpur beds of the Rajmahal hills (*q. v.*), and that both correspond to the lowest stage (Pachmarhi) of the Mahadeva series; it must be remembered that the generally unfossiliferous nature of the Mahadeva beds their softness and ease of weathering render their recognition a matter of some uncertainty.

Rajmahal Hills.—In the Rajmahal hills of Bengal, the Lower Gondwanas are overlain by a succession of coarse sandstones, grits and conglomerates, named after the village of Dubrajpur, situated about forty miles north of Suri. Shaly sandstones are occasionally met with but fine-grained beds are not common. Most of the coarser members are ferruginous, and a frequently occurring form of conglomerate, precisely similar to one found in the supposed Mahadeva beds of the

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[1] A. Jowett. *Mem.* LII, pt. 1, 137 (1925).

[2] E. R. Gee. *Mem.* LXI, 61 (1932).

[3] W. T. Blanford. *Mem.* III, 131 (1861).

Damodar valley, consists of quartz pebbles in a ferruginous matrix.[1] The Dubrajpur sediments have petrological resemblances to the Barakars and were at one time equated with the Kamthis,[2] but the discovery by Mr. G. V. Hobson of specimens of *Unio* in the Dubrajpurs has established their relationship to the overlying Rajmahal series in spite of their resemblance to Damuda sandstones;[3] they are, in fact, "infra-trappean" to the Rajmahal volcanic series, and probably belong to the basal part of the Mahadeva succession.

Along the western scarp of the Rajmahal hills, the rocks of the Dubrajpur stage rest partly upon Barakars and partly upon the Archæan, the Barakars being repeatedly overlapped by the Dubrajpur beds in a manner which shows the two to be quite unconformable one to the other; the upper boundary of the Dubrajpurs with the Rajmahal beds is also an unconformable one. The greatest thickness of the stage in the Rajmahal area does not exceed 450 feet. Some specimens of a cycadaceous plant (*Ptilophyllum*) were once found near the southern extremity of the hills in the uppermost beds underlying the Rajmahal trap, but there is some little doubt as to whether this fossiliferous band may not belong to the Rajmahal series itself.[4]

RAJMAHAL SERIES.

One of the best known series of the Upper Gondwana division derives its name from the Rajmahal range in Bengal, extending from the Ganges at Colgong southwards to the neighbourhood of Suri in Birbhum, a distance of some hundred miles, throughout which the beds are displayed. Some outcrops of Upper Gondwana deposits along the east coast of the Peninsula include fossiliferous rocks which have been spoken of freely as Rajmahal but which are probably younger. The Rajmahal series may be divided into two phases or stages, the mutual relationship of which may be expressed in a general way as follows:[5]—

2. The Rajmahal Traps.
1. The Rajmahal Plant Beds.

In the type area, the Rajmahal volcanic beds, resting on the Dubrajpur stages are interbedded with sedimentary bands, the lowest of which are the Rajmahal Plant Beds. It will be convenient, therefore, to consider these two stages—if they can be so called—conjointly. The sedimentary bands, insignificant in thickness but some of them rich in plant remains, are held to have been deposited during the intervals which elapsed between the volcanic outbursts, and the possibility that any of the basal sheets are sills and not flows is remote. These conclusions are based on the facts that the separate bands of shale and sandstone differ from each other in mineral character, and that whilst the upper surface of some of the shaly beds has been hardened and altered by contact with overlying basalt, the lower surface is never so affected; furthermore, many of the traps are amygdaloidal.

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[1] V. Ball. *Mem.* XIII, pt. 2, 45 (1877).

[2] E. Vredenburg. "A Summary of the Geology of India", 2nd Edit., 129 (1910).

[3] *Gen. Rept., Rec.* LXII, 145-146 (1929).

[4] O. Feistmantel, *Pal. Ind.*, Ser. XII, Vol. III, Pt. 2, p. 69 (1880). The specimens of *Phyllotheca robusta* Feistm. from Dubrajpur are labelled doubtfully as of Raniganj or Rajmahal age, and are compared with a Permian species—*P. schtschurowskii* (*sic*) Schmalh. from the Kusnezk basin of southwestern Siberia. The Raniganj stage, however, does not appear to have been recognised in the Rajmahal hills and, since *P. robusta* has been identified in the Lower Bowen series (Lower Permian) of Queensland, the Indian specimens probably came from rocks mapped as Barakar which crop out in the neighbourhood of Dubrajpur village.

[5] The term "Rajmahal" has frequently been used for the Rajmahal Plant Beds. The latter are best regarded as a stage, forming only a small proportion of the Rajmahal series and occurring at its base. The volcanic beds forming the upper and greater portion of the Rajmahal series should correspond approximately with the ill-defined Kota stage of the Godavari valley.

The sedimentary beds are composed chiefly of hard, white and grey shale, carbonaceous shale, white and grey sandstone, and hard quartzose grit. No fossils have been found in the upper inter-trappeans, the plant remains being restricted to the older intercalations. Some of the clays are suitable for the manufacture of porcelain, while some of the sands are said to be sufficiently pure for use in glass manufacture.[1]

The trap rocks are all dark in colour, and vary from a very tough, fine-grained micro-dolerite ("anamesite"), ringing under the hammer and fracturing with edges almost as sharp as those of a quartzite, to a comparatively soft, coarsely crystalline basalt, usually containing olivine in large quantities. The amygdules in the amygdular varieties usually contain some form of silica such as agate, chalcedony or rock-crystal ; less frequently, zeolites are found, stilbite being the commonest, natrolite less abundant, and analcime the least often seen. It is not usual to find the cavities lined with green earth, as is so frequently the case amongst the amygdaloidal forms of the Deccan Trap. Some of the traps carry palagonite which appears to consist of zeolitised portions of an original glassy magma.[2]

Very little light is thrown on the source of the basaltic rocks by any observations within the central part of the Rajmahal area, but there is one instance of an intrusive mass which may possibly mark the site of an old volcanic outburst; close to Simra, twenty-two miles S.S.E. of Colgong, there occurs a group of small conical hills, composed of pinkish trachyte, porphyritic in places, and surrounded by Damuda rocks. The ground is much obscured by superficial deposits, but there is some reason for supposing that the core of a volcanic vent is here exposed, made up of the more acid residuum of the latest discharge. Dykes are rare in the Rajmahal area itself but basic dykes and intrusions, some of them believed to be of Rajmahal age, are abundant in the coalfields of the Damodar valley, and in the portion of Birbhum lying southwest of the Rajmahal hills both dykes and cores of basalt are common. Which of these intrusions belong to the Rajmahal and which to the Deccan Trap, it has not in every case been determined, and the possibility of the Simra exposures marking the vent of a Deccan Trap extrusion cannot yet be definitely put aside. As in the case of the Deccan Trap, the original source of the Rajmahal extrusions is difficult to determine, but it is possible that the principal vents lay to the southwest and probably took the form of fault fissures ; on the other hand, they may have been covered by the Ganges alluvium to the east. Whether or not one of the foci of eruption occupied the region immediately north of the Raniganj coalfield, it is far from improbable that the bedded traps of the Rajmahal hills had originally a considerable extension to the southwest and south, though no single outlier has survived to confirm the inference. There is, in fact, a probability that a large tract in the Damodar valley, including the whole Raniganj field, was once occupied by bedded traps. The occurrence of Rajmahal traps in the Abor hills, and possibly also in the Dafla hills, of the eastern Himalaya, has already been described.

The lithological resemblance between the Rajmahal and the Deccan traps is curiously close and aroused much comment in view of the fact that a whole geological system separates the end of one from the beginning of the other[3] ; equally curious, and accumulatively so, is the lack of resemblance between the Rajmahal trap and that of Sylhet, though the periods of the two must approximately coincide. Whether or not we regard the Rajmahal volcanic activity as a forerunner of the Deccan Trap, it seems justifiable to look upon it as an accompaniment of some of the earth movements which faulted down the Gondwana sediments along the lines of their basins. In chemical composition, the resemblance to the Deccan traps is extremely close, as the following analyses by H. S. Washington show.[1]

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[1] M. Stuart. *Rec.* XXXVII, 191-198 (1908) ; *Ibid.*, XXXVIII, 133-148 (1909).

[2] C. S. Middlemiss. *Rec.* XXII, 226-234 (1889).

[3] C. A. Mc Mahon. *Rec.* XX, 104 III (1887) ; C. S. Middlemiss. *Ibid.*, XXII, 226-227 (1889).

Chemical analysis.

By eliminating the water-content in the case of the Rajmahal and Bombay specimens, it will be seen that the rocks are still nearer to each other in composition. The specific gravity of the Rajmahal specimen was found to be 2·886.

	Rajmahal trap from Ramchandarpur.		*Deccan trap; mean of three analyses, Bombay Presidency.*		*Deccan trap; mean of four analyses, Central Provinces.*
		(Dry)		(Dry)	
SiO_2	53·45	54·00	51·69	53·06	49·51
Al_2O_3	15·24	15·40	14·72	15·11	13·05
Fe_2O_3	1·26	1·27	2·83	2·90	3·06
FeO	8·20	8·29	10·87	11·16	10·39
MgO	5·83	5·89	4·18	4·29	5·71
CaO	9·32	9·42	8·20	8·42	10·18
Na_2O	3·03	3·06	3·25	3·34	2·25
K_2O	1·12	1·13	0·93	0·95	0·51
H_2O+	0·56	..	2·01	..	1·99
H_2O-	0·47	..	0·58	..	0·32
TiO_2	0·50	0·51	0·63	0·65	2·34
P_2O_5	0·78	0·79	0·42	0·43	0·37
MnO	0·13	0·13	0·11	0·11	0·22
SO_3	..	..	..	..	0·02
Total	99·89	99·89	100·42	100·42	99·92

The bedded basaltic traps of the Rajmahal hills, with their associated sedimentary beds, attain a thickness of at least 2,000 feet, of which the non-volcanic portion never exceeds 100 feet in the aggregate, individual beds varying from 2 to 30 and averaging between 4 and 5 feet in thickness. Ten distinct flows of trap, averaging 75 feet each in thickness, have been mapped by Mr. G. V. Hobson who has noted a few dolerite dykes in association with the lavas, and has drawn attention to the faulted condition of the Rajmahal succession[2]; the total number

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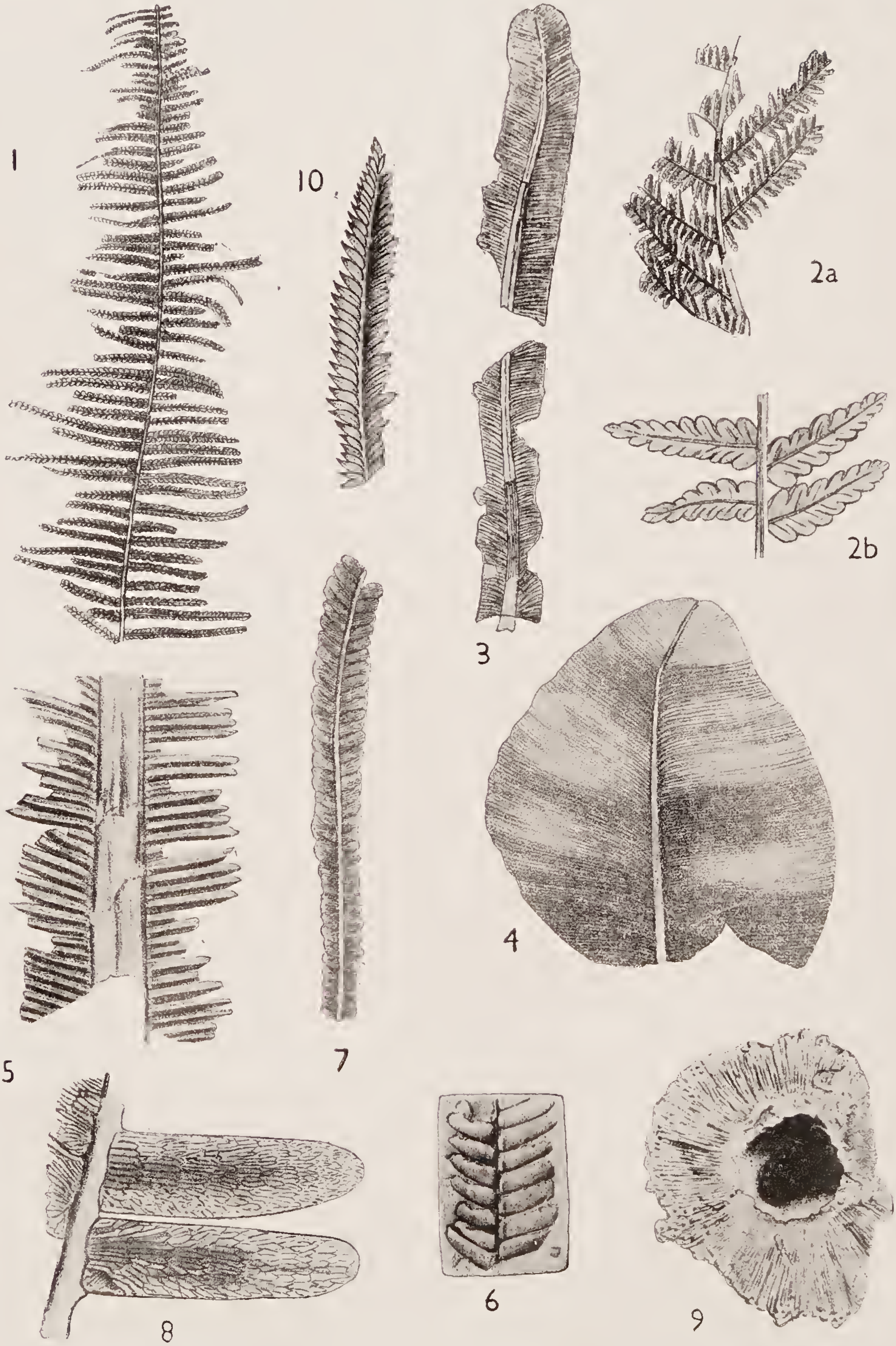
[1] *Bull. Geol. Soc. Amer.*, Vol. 33, p. 774 (1922).

[2] C. S. Fox. *Mem.* LVIII, 204 (1931).



RAJMAHAL FLORA.

1. *Gleichenites gleichenoides* O. & M. Schimp. 2. (a,b) *Pecopteris lobata* Oldh. 3. *Taeniopteris spatulata* McCl. 4. *Taeniopteris lata* Oldh. 5. *Nilssonia rajmahalensis* (Morr). 6. *Ptilophyllum acutifolium* Morr. 7. *Otozamites bengalensis* O. & M. 8. *Dictyozamites falcatus* O. & M. 9. *Williamsonia indica* Sew.
10. *Elatocladus conferta* Feistm.

G. S. I., Calcutta.

of flows must be more than double the number distinguished by Hobson. Many of the dykes appear to belong to the Deccan Trap and not the Rajmahal period.[1]

The Rajmahals rest with general parallelism on the grits and coarse sandstones of the Dubrajpur stage, but there are several instances of overlap, and in one locality at least there is evidence of denudation of the Dubrajpur beds before the deposition of the Rajmahals. It is quite likely that the Dubrajpur beds of the Rajmahal hills and Damodar valley were at one time completely covered by the Rajmahal traps.

The difference in age between the Rajmahal series on the one hand and all the Lower Gondwana rocks including the Damudas and Panchets on the other, is well illustrated by a change in the flora and by the much greater amount of disturbance to which the Damuda rocks have been subjected. The Rajmahal traps of the Rajmahal hills are almost horizontal, though not quite so free from faulting as they were at first thought to be. The igneous intrusions of the Damodar valley are more fully considered later.

By far the greater number of the Rajmahal fossils have been obtained from two bands of fine-grained, light-coloured shales, the lower 10-15 feet and the upper 25-30 feet thick, separated from each other by a lava flow and both underlain and overlain by other beds of trap with intercalations of sandstones and shale ; in the Pachwara coalfield, the lowest of the inter-trappean beds is a sandstone containing specimens of *Unio* like those found in the Dubrajpur beds. The following is a list of the plant remains identified from the two shale bands :—

Equisetales.—	
Equisetites rajmahalensis Schimp.	
Lycopodiales.—	
Lycopodites gracilis (Morr.).	Referred to in the past as *Cheirolepis* or *Arauearites* ; found in the Lower Jurassic of Argentina and probably identical with the English Jurassic *L. falcatus* Lind.
Pteridospermae, Filicales aut Plantœ incertae sedis.—	
Marattiopsis macrocarpa (Morr.).	Genus referred to in the past as *Asplenites* or *Pecopteris*.
Thinnfeldia indica Feistm.	Found in the Lower Jurassic of Victora ; identical with *Pecopteris salicifolia* Morr.
Gleichenites gleichenoides (Morr.).	A very abundant form ; found in the Lower Cretaceous of Queensland and identical with *G.* "*bindra bunensis* Schimp".
Cladophlebis denticulata Brongn.[2]	
Coniopteris hymenophylloides Brongn.	The equivalent of "*Sphenopteris arguta*" L. & H.".
Sphenopteris hislopi (O. & M.).	
Pecopteris lobata O. & M.	
Danaeopsis rajmahalensis (Schimp).	
Cycadophyta.—	
Ptilophyllum acutifolium Morr.	Genus referred to in the past as *Palæozania* includes Feistmantel's "*Otozamites abbreviatus.*"
,, *cutchense* Morr.	Almost certainly indistinguishable from *P. affine* Feistm. *P. rigidum* Schimp, *Otozamites angustatus* Feistm., *O. hislopi* Oldh. and *O. gracilis* (Kurr.) ; almost indistinguishable from the English Jurassic *P. pecten* Phill. which is perhaps the equivalent of *P. acutifolium.*[3]
Williamsonia microps Feistm.	Probably the equivalent of *W. blanfordi* Feistm., a strobilus from Cutch which might well belong to the plant which bore the fronds of *Ptilophyllum acutifolium.*
,, *indica* Sew.	Equivalent to *W. gigas* Carr.
,, cf. *setosa* Nath.	
,, *sewardiana* Sahni.	Flowers of *Ptilophyllum cutchense.*[4]

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[1]. A. S. Kalapesi, S. K. Chhapgar and R. N. Sukheswala. *Quart. Journ. Geol. Min. & Met. Soc. Ind.*, XV 127-131 (1943).

[2] A. C. Seward and B. Sahni. *Pal. Ind.* New Ser., Vol. VII, No. 1, 20 (1920).

[3] A. C. Seward. "Fossil Plants", III, 515. (1910).

[4] Professor B. Sahni has essayed an interesting reconstruction of this plant [*Pal. Ind.*, New Ser., Vol. XX, *Mem.* 3, Pt. III(1932)].

Bucklandia indica Sew.,	Stems which bore the *Williamsonia sewardiana* flowers and the *Ptilophyllum cutchense* fronds.
Otozamites bengalensis (O. & M.),	Found also in the Jurassic of W. Australia.
,, *abbreviatus* Feistm.,	Found also in the Jurassic of the Antarctica. Inseparable from *Ptilophyllum*, according to Seward.
Dictyozamites [" *Dictyopteris* "] *falcatus* (Morr.),	
,, ,, ,, var. *obtusa* (Morr.),	
Tæniopteris ("*Macrotæniopteris* ") *lata* Oldh.,	(Found also in S. Africa),
,, ,, *morrisi* Oldh.,	
,, ,, *musæfolia* Oldh.,	
,, ,, *ovata* (Schimp),	
,, ,, *crassinervis* (Feistm.),	
,, ("*Angiopteridium* ") *spatulata* (McClell.),*	
,, ,, cf. *macclellandi* (Morr.),	
,, ,, *ensis* Oldh.,	
Nilssonia princeps (O. & M.),	Genus referred to in the past as *Pterophyllum* ; *Anomozamites* or *Platypterigium*.
,, *rajmahalensis* (Morr.),	Synonymous with " *Eycadites rajmahalensis* Morr.," "*C. confertus* Morr." and " *C. blanfordianus* Oldh. "
,, *bindrabunensis* Sew. & Sahni,	Synonymous with " *Pterophyllum rajmahalense* O. &. M."
,, ["*Anomozamites* "] *fissa* (Feistm.),	
,, ["*Pterophyllum* "] *medlicottiana* O. & M.,	
,, *morrisiana* O. & M.,	Synonymous with " *Pterophyllum rajmahalense* var. *lata* O. & M.", " *P. carterianum* Oldh." and " *P. propinquum* Göp." and probably " *Pseudoctenis ensiformis* ". Found also in the " Lower Jurassic of Argentina,
,, *orientalis* (Heer),	
,, *compta* (Phill.),	Found also in the Jurassic of New Zealand.

Crookshank refers to *Nilssonia orientales* and *N. compta* as " Rajmahal forms". (*Mem.*, LXVI, 252 (1936). Both species have been found in Afghanistan (*Pal. Ind.*, New Ser., IV, *Mem.* 4, 28 and 33), but I cannot find any record of their occurrence in the Rajmahal. If there is any doubt about it, these two species should be deleted from the above list. If it is certain that they are Rajmahal species, it should be stated opposite each that this form has been found in Afghanistan. *Anomozamites nilssonia* is another. This should also be deleted if there is any doubt; the name arouses one's suspicion.

Anomozamites cf. *nilssonia*
Podozamites ("*Pterophyllum* ") *distans* (Presh).

Coniferales.—

?*Dadoxylon* (*Araucarioxylon*) *rajmahalense* Sahni.[1]	
Strobilites pascoei Sahni,	Affinities obscure ; perhaps the fructification of the wood, *Pentoxylon*.[2]
Coniferocaulon sp.,	A decorticated conifer stem.[3]
Conites rajmahalensis Sahni,	A female cone.[4]
Elatocladus conferta (O. & M.),	Genus referred to in the past as " *Cunninghamites* " or " *Palissya*". Found also in the Jurassic of Victoria, New Zealand and Antarctica.
Retinosporites ["*Palissya* "] *indica* (O. & M.),	
Pagiophyllum [" *Pachyphyllum* "] cf. *peregrinum* (Schimp),	
Athrotaxites [" *Echinostrobus* "] *indicus* O. & M.,	
Brachyphyllum expansum (Sternb.),	A European Jurassic form,[5]
,, *mamillare* Brongn.,	(" *Echinostrobus rajmahalensis* Feistm.")
Coniferous wood (indeterminable).	

Angiospermae.—

Homoxylon rajmahalense Sahni,	From an unknown horizon and locality in the Rajmahal hills.[6]

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*Perhaps the deciduous leaves of *Pentoxylon*, a wood of coniferous type, according to the researches of Messrs. A. R. Rao and B. P. Srivastava ; if so, it is, as Professor Sahni points out, an interesting combination of cycadean and coniferous features (*25th Ind. Sci. Congr.*, Calcutta, 1938, *Pres. Addr. Bot. Sect.*).

[1] *Pal. Ind.*, New Ser., XI, Pt. II, 69 (1931) ; locality unknown but in the Rajmahal hills.

[2] B. Sahni. *Pres. Addr. Bot. Sect. 25th Ind. Sci. Congr.* (1938).

[3] B. Sahni. *Pal. Ind.*, New Ser., XI, Pt. II, 78 (1931).

[4] *Pal. Ind.*, New Ser., XI, Pt. I, 36 (1928).

[5] *Ibid.*, p. 20.

[6] *Pal. Ind.*, New Ser., XX, *Mem.*, 2 (1932).

Recently many of the above species have been found in other localities and with them a few new forms which must now be added to the Rajmahal flora :[1]

Filicales.—
Cladophlebis indica O. & M.,
Sphenopteris rajmahalensis Sahni & Rao,
Rhizomopteris sp.,
Sagenopteris bhambhanii Jacob,[2]
Tinpaharia sinuosa Jacob. Probably the vegetative organs of *Coniopteris hymenophylloides*,
Hausmannia (?) sp.

Cycadophyta.—
Ptilophyllum tenerrimum (Feistm.),
Otozamites parallelus (Feistm.),
Pterophyllum incisum Sahni & Rao,
Dictyozamites indicus Feistm.,
,, *hallei* Sahni & Rao,
Taeniopteris macclellandi O. & M.,
Zamites proximi Feistm.,
Cycadolepis ? sp.,
Cycad seeds, probably of *Nilssonia*.

Coniferales.—
Ontheodendron florini Sahni & Rao,
Araucarites sp. (cone scales),
Elatocladus tenerrima (Feistm.),
Conites hobsoni Sahni. Perhaps the cones of *Brachyphyllum mamillare*.[3]

Incertæ sedis.—
Podozamites sp.,
Lycoxylon indicum Sriv. Perhaps equivalent to *Lycopodites gracilis* Morr.,
Pentoxylon sahnii Sriv. Probably the stem of *Tæniopteris spatulata*,[4]
Nipanioxylon guptai Sriv.[5]
Nipaniostrobus sahnii Rao. A female cone, probably of the same plant as *Masculostrobus*,[6]
Sakristrobus sp.[7]
Masculostrobus rajmahalensis Rao.[8] A male cone,
Rajmahalia paradoxa Sahni & Rao. Perhaps a Bennettitalean flower.
Winged pollen and spores. Probably *Pityosporites* sp. and including *Podosporites tripakshi* Rao, a three-winged spore, and *Alisporites jurassicus* Rao, a two winged variety.

Many of the forms in the above lists are confined to the Rajmahal Plant Beds. *Rajmahalia* is a new plant, probably gymnospermous, the remains including scarred axes, silicified wood and seeds, and what appears to be an inverted funnel-shaped organ over the receptacle of a Bennettitalean flower. The commonest genera in this flora are *Nilssonia* and *Ptilophyllum*. *Williamsonia sewardi* is a flower very similar to *W. scotica* Sew.,δ borne specially on a cycadean stem (*Bucklandia indica*) covered with an armour of persistent leaf-bases from which, as Sir Albert Seward has shown, sprang the foliage known under the name of *Ptilophyllum cutchense.*[1] The most striking feature in the above list is the marked change in the forms of life as compared with those in the Lower Gondwana. In Bengal at least, there is as great a break in the flora as there is in the stratigraphy, the vegetation of the Upper being strikingly different from that of the Lower Gondwana. The most prevalent forms in the latter are Equisetaceæ and leaves of the *Glossopteris* type; cycads, although appearing as early as Barakar (Lower Permian) times, occupy, only a subordinate position in the flora. In the Upper Gondwana, and especially in the Rajmahal series, on the other hand, the Cordaitales, the glossopterids and a host of other fern-like plants have disappeared, the Cycadophyta predominate and are frequently so abundant individually as to form the mass of the vegetation, and the rival group of the conifers has made its appearance.[2] The cycads, especially *Ptilophyllum acutifolium*, are as abundant in, and as characteristic of, the Rajmahal series as *Glossopteris* and *Vertebraria* are in the case of the Damudas.

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[1] B. Sahni & A. R. Rao. *J. A. S. B.*, New Ser., Vol. XXVII, 186—7 (1931).
[2] *Journ. Ind. Bot. Soc.*, XVIII, 204-(1940).
[3] B. Sahni. *Proc. 19th Ind. Sci. Congr.*, 322 (1932).
[4] *Ibid.*, 285; also *25th Ind. Sci. Cong.* (1938)., B. P. Srivastava. *22nd Ind. Sci. Congr.*
[5] *Ibid.*, 285.
[6] A. R. Rao. *Proc. 25th Ind. Sci. Congr.*, 153 (1938) ; *Gen. Rept. Rec.*, 73, 24 (1938).
[7] *Journ. Ind. Bot. Soc.*, XVIII, 204 (1940).
[8] *Ibid.* p. 36.

The period of the Rajmahal flora has generally been regarded as the Lias; Feistmantel was of opinion that it exhibits some relations to Rhætic forms.[3] The Rajmahal traps no doubt range up into the Oolites, and may be regarded as corresponding to some extent to the ill-established Kota stage.

BASIC INTRUSIVES OF THE DAMODAR VALLEY AND OTHER PARTS.

Two Phases.—In the Damodar valley, the Rajmahal series is probably represented by some at least of the dykes and sills of trap rock which seam the rocks of the coalfields. The igneous intrusions of these regions are of two kinds, corresponding to a difference in age, and consist in one case of mica peridotites or lamprophyres, and in the other of dolerites or basalts. The peridotite or ultra-basic phase is closely associated with faulting and with the coal seams; and has materialised in a very irregular manner; in these features its intrusions differ from the doleritic or basaltic dykes of the basic phase whose trend across the strata is regular, quite unattracted by the coal seams and almost uninfluenced by fault planes.[4] This may well be due, as Fox suggests, to the fact that all the more easily filled fissures had been appropriated by the earlier peridotite intrusions. Actual mutual contacts between the ultra-basic and basic types have been observed in the Giridih field, where a large dyke of basalt cuts a thin dyke of peridotite;[5] furthermore, the dolerites and basalts are to be seen continuous across faults or across coal seams which have been intruded by peridotite sills. It is concluded, therefore, that the peridotite is definitely older than the dolerite, but since the former is younger than most at least of the faulting and traverses beds as high as the Panchets, its priority is one of no excessive degree. Neither the peridotite nor the dolerite show signs of crushing. The absence of peridotite intrusions from beds above the Panchets might seem to favour the deduction that the ultra-basic intrusions took place at the end of the Lower and before the beginning of the Upper Gondwana, but such absence is of limited significance in view of the smallness and infrequency of the outcrops of these supra-Panchet beds in the Damodar valley, and the ultra-basic intrusions may be regarded provisionally as of Rajmahal age.

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[1] *Gen. Rept. Rec.*, LXV, 22 (1931).

[2] B. Sahni. *Proc. 8th Ind. Sci. Congr.*, clxiii, clxiv (1921).

[3] *Pal. Ind.*, Ser. II, Vol. 2, p. 158 (1877).

[4] C. S. Fox. *Mem.* LVI, 115-127 (1930).

[5] T. H. Holland and W. Saise. *Rec.*; XXVIII, 130 (1895).

Mica-peridotites.—The mica-peridotite type intrusions are to be found in the Raniganj, Jharia, Bokaro, South Karanpura, Giridih and Jainti coalfields as well as in the Lower Gondwanas of the Darjeeling Himalaya, but are absent from the more westerly coal basins and from the Rajmahal area. Occasionally the peridotites, like the dolerites, occur as well-marked vertical dykes of regular direction, with a width in some cases of 30 feet or even twice that amount, and giving off few or no branches. The majority, however, although of the same composition, are characterised by an irregular habit due, it is thought, to an unusual degree of fluidity, and are less than three feet across, grading down in size to minute veins and thin films. Occasionally they thicken to boss-like masses, and ramifications in the form of both dykes and sills and may vary in thickness in the same intrusion from a few inches to over a hundred feet ; in certain areas they form an intricate network and have played havoc with the coal seams which they have invaded. As would be expected, they show a predilection for the coal seams, as offering the easiest path, especially along planes of special weakness such as the top and bottom of a seam. This predilection is well seen in the Raniganj field ; in those parts of the basin in which the thick seams of the Upper Damuda have apparently died out, the peridotite intrusions are largely confined to the Barakar stage, in which the thick seams persist. Peridotite sills, the pests of the coalfields, are on the whole more widespread in the Barakar than in the Raniganj coal measures, the reason being presumably that the former stage was first to be reached by the uprising magma. The sills, lenticular in section, usually range up to three or four feet in thickness and extend in the form of flat, root-like horizontal apophyses ; the anastomosing of such sills within the same seam may spoil the whole of it. The peridotites are always decomposed at the surface producing a soft, crumbling, buff coloured earth.

The peridotite intrusions are intimately connected with the faulting of the Gondwanas and are always more abundant in those parts of the coal seams which lie near faults. Occasionally, the more vertical intrusions transgress a line of faulting, especially the line of a minor fault, but the major dislocations have served as the main channels up which the magma found its way until a suitable stratum was reached along the bedding planes of which it could digress with ease in a horizontal direction ;[1] there are many instances of a dyke following the line of a prominent fault, or extending parallel to and within a very short distance of it.

While the term, mica-peridotite, is applicable to many of these readily weathering ultra-basic intrusives, and especially to those in the Giridih coalfield, many of them are more of the nature of lamprophyres, and others exhibit differences from both these types.[2] Coarse and finely crystalline varieties, with or without visible crystals of altered olivine, are sporadically distributed ; a few of the dykes are amygdaloidal. Distinct flow structure is occasionally seen in these rocks, even in the narrow dykes and pipes. The peridotites possess a noticeable feature in the presence of specks or plates of biotite and, in some cases, more especially in the Darjeeling intrusions, of anthophyllite ;[3] the normal intrusion, however, is frequently cut up by veins of material almost free from biotite. Among the few minerals recognisable in these ultra-basics under the microscope, quartz is seen intergrown with felspar or occurring in vesicular cavities suggestive of geodes.[1] In all varieties the most characteristic constituent is apatite, and analyses show the rock to be much more highly phosphatic than is customary in normal peridotites or lamprophyres. Whether this very high phosphorus-content—over 5 per-cent. of P_2O_5 (corresponding to 11 per cent. of apatite) in some of the Giridih peridotites—is derived from the coal whose phosphorus percentage is higher than usual, or whether it comes from the surrounding metamorphic rocks, it would be difficult to say; certain it is that the metamorphic rocks which cradle the coal-fields of the Damodar valley and adjacent areas are abnormally high in phosphorus, and it is not unlikely that both the peridotites and the coal derived their unusually high phosphorus-content from the ancient rocks of the catchment area. Unlike the corresponding rocks in South Africa, the peridotites of the Indian Gondwanas have not been found to carry diamonds.

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[1] E. R. Gee. *Mem.*, LXI, 84 (1932) ; C. S. Fox *Ibid.*, LVI, 119 (1930)

[2] E. R. Gee. *Mem.*, LXI, 88 (1932).

[3] T. H. Holland. *Rec.*, XXVII, 130 (1894).

The effect of the peridotites on the coal is the production of a natural coke or semi-coke, known in the vernacular as *jhama*. This dull, dense, hard product formed at great depth under immense pressure, varies in consistency according to its distance from the igneous intrusion, but much of it still contains 10 or 11 per cent. of volatile matter; only along the actual contact with the intrusives as a rule, is there complete caking. Even the narrow dykes, where they pass through coal seams, are bordered on either side by a zone of coke two or three feet thick, possessing a beautiful columnar structure caused by the contraction resulting from the loss of volatile matter; even along the small cracks between the columns, thin films of igneous matter have found their way.[2] The "blowers" of gas, sometimes met with in the coal mines, are perhaps relics of this ancient distillation, but no trace of tar has been observed.[3] Although an excellent smokeless fuel, *jhama* is difficult to extract and the cost of mining it is against its exploitation. In the Jharia field alone the coal ruined by igneous intrusions within 2,000 feet of the surface amounts to hundreds of millions of tons. This phenomenon of natural coke formation must not, of course, be confused with that of "burnt outcrops"; it has been noted also in Bokaro, Darjeeling and the Pench valley coalfields as the effect of either the peridotites or the dolerites.

The sandstones and shales of the Damuda series have likewise not escaped baking in the immediate vicinity of the peridotite intrusions, the sandstone in some cases having been fused to a rock having such a close resemblance to a rhyolite that it might be mistaken for such.[4] Such drastic effects point to an exceptionally high temperature.

Dolerite and basalt.—Almost every coalfield of the Gondwanas contains dykes and occasionally sills of dolerite and basalt and in most cases, this igneous material is definitely of Deccan Trap age.[5] The nearest post-Palæozoic effusives to the dolerite dykes in the lower part of the Damodar valley are the Rajmahal traps. Geographically, the Damodar valley dykes are a link between the traps of Rajmahal (middle Jurassic) and the lavas of the Deccan Trap (uppermost Cretaceous to Eocene), and the question whether this link is not at the same time a chronological one might well be asked. We have already had an example in the case of the Panjal Trap of a volcanic phase stretching across the time-scale—in other words, beginning and ending earlier in one place than it did in another. It would not be impossible for the Deccan Trap outbursts to have commenced early in Jurassic times in the Rajmahal area, and to have spread slowly westwards, the bulk of this vast effusion dating from the end of the Cretaceous. Nevertheless, in spite of the fact that the Rajmahal traps and the Deccan traps are practically indistinguishable from each other petrologically, there is no definite evidence of continuous vulcanicity from Rajmahal to Deccan Trap times, and it is safer for the present to regard the two as distinct suites of intrusions. Beyond the Damodar watershed, dolerite dykes are found in the Aurunga, Hutar and Daltonganj coalfields of Palamau, but are uncommon and are unaccompanied by peridotites; here they have every appearance of belonging to the traps of the Deccan, as undoubtedly do the dolerite dykes of the Satpura and Rewah areas. In the Darjeeling area, dolerites are absent and the dykes are composed entirely of the peridotite variety. That the dolerite and basalt dykes of the Rajmahal, Raniganj, Jharia, Giridih, Jainti, Bokaro and Karanpura coalfields are considerably older than they are in other Gondwana regions does not appear to be probable, and is negatived by some investigations on the ratio of the lead content to that of uranium and thorium in the dykes under consideration.[1] Assuming the age of an igneous rock to be:

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[1] C. S. Fox. *Mem.*, LVI, 115 (1930).
[2] T. H. Holland & W. Saise. *Rec.*, XXVIII, 122 (1895).
[3] C. S. Fox. *Mem.*, LVII, 60 (1931).
[4] T. H. Holland. *Rec.*, XXVII, 130 (1894).
[5] C. S. Fox. *Mem.*, LVI, 22 (1931).

$$\frac{\text{per cent. of lead}}{\text{per cent. of uranium} + 0{\cdot}36 \text{ per cent. of thorium}} \times 7{,}600 \text{ million years,}$$

the age of the dolerite and basalt dykes in the Rajmahal area, as well as in the Raniganj, Jharia and Giridih coalfields, works out to be much the same as that of the Deccan traps, most of which are early Tertiary. The relationships of the dykes in the seven coalfields mentioned above make it advisable to describe them here instead of under the heading of the Deccan Trap to which they properly belong.

The dolerite and basalt dykes of the above-mentioned areas are in most cases readily distinguishable in the field from the peridotite intrusions by their greater thickness, their characteristic jointing and their spheroidal mode of weathering; they are sometimes as much as 100 feet thick. They give off no branches and are regular in trend except for occasional slight "jinks" which are suspected to be the result of late minor faults. Only occasionally, as in the Karanpura field[2], are they associated or coincident with the main lines of faulting; they are undeflected by the coal seams and, unlike the peridotite intrusions, they extend beyond the boundary of Gondwana outcrops into the gneiss. The dykes are arranged usually in two sets more or less at right angles to each other, an arrangement no doubt determined by the direction of the joint-planes or foliation-planes of the intruded rocks; in Jharia, for instance, the two sets run W.N.W.-E.S.E. (parallel to the general trend of the basin) and N.N.E.-S.S.W. The effect of the dolerite upon the coal, where a dyke crosses a seam, is very much less than that produced by the peridotite or lamprophyre, in spite of the greater average thickness of the less basic rocks; the margins of coke are less conspicuous, and the total result of the intrusion, from an economic point of view, has not been very serious. The material of the dolerites makes a useful road metal.

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[1] A. S. Kalapesi, S. K. Chhapgar and R. N. Sukheswala. *Quart. Journ. Geol. Min. & Met. Soc. Ind.*, XV, 127-131 (1943).

[2] A. Jowett. *Mem.*, LII, 143 (1925).

The number of these dykes is said to diminish gradually in the coalfields of the Damodar valley from east to west. In the Jhilmili coalfield of the Sarguja region, intrusions of dolerite believed to be of Deccan Trap age are to be observed along the line of the northern boundary fault and may possibly have been contemporaneous with the dislocation.[1] Outside the coalfields there is a danger of confusing the Rajmahal or Deccan Trap dykes with much older eruptions such as those in southern Monghyr, Hazaribagh and Chota Nagpur, but there is not the same abundance of extensive basaltic intrusions in these areas as there is in Birbhum.

SYLHET TRAP.

Belonging in all probability to the period of the Rajmahal suite of igneous effusion is a trap found in the southern escarpment of the Shillong plateau and known as the Sylhet Trap. For a distance of about forty miles, it is extensively and interruptedly exposed along the margin of the plateau to the north of Sunamganj in the Sylhet district of Assam. The main outcrop has a very constant width of from 2¼ to 2½ miles, but there is a rapid decrease in thickness in the Khasi Hills where, from a total of 1,500 feet it diminishes in a comparatively short distance to a few feet.[2] Except along the north, all the outcrops are bounded by the overlying Cretaceous. The northern boundary is with the gneiss or with the Shillong series ; the peculiar straightness and coincident E.-W. alignment of the northern boundaries of the outcrops have suggested the presence of a fault, but exactly similar straight and parallel boundaries are seen between the trap and the Cretaceous, between the Cretaceous and the Eocene (or Palæocene) and between the latter and the Upper Tertiary, and would seem to be the result rather of an extremely regular folding, and of the long straight master joints which afterwards affected the overlying Cretaceous sandstones as well as older rocks. Medlicott has expressed the opinion that the trap was piled up against a precipitous face of the metamorphic rocks[3] ; in one place the trap has the appearance of lying in a pocket of the gneiss.

For the most part, the Sylhet trap flows consist of dark blue, bedded spheroidal andesites, showing a rough stratification and dipping to the south and southwest at angles varying from 19° to 25°. Hornblende and augite are both present, the former often showing " resorption borders."[4] In other places the rock is basaltic, the felspars ranging from acid oligoclase to basic labradorite, and some varieties contain olivine, which is always serpentinised or chloritised.[5] The rock may be earthy, compact or amygdaloidal, the steam cavities in the last being usually filled with calcite. Some of the olivine-bearing varieties are said to be very like common forms of the Deccan Trap. Amongst the lavas, ash beds are not rare, and large lapilli are occasionally seen ; some of the ashes are described as friable, and appear to be characteristic of the upper horizons.

Sometimes the dip of the trap agrees roughly with that of the overlying Cretaceous sediments, but there can be no doubt that a break occurs between the two and that the sandstones rest on a denuded surface of the lava ; such unconformity is well seen in the Tharia river section. The Sylhet traps and ashes are exposed in valleys and low-lying tracts, and are confined to the area affected by the monoclinal fold along the southern edge of the plateau. The formation is of considerable thickness and, therefore, probably of much greater extent originally ; its southward and westward extension is now covered, partly by Cretaceous and Tertiary deposits, but mostly by the Recent alluvium of Sylhet and Mymensingh. It may even be continuous beneath these younger sediments with the Rajmahal traps, the nearest exposure of which is about two hundred miles distant.

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[1] C. S. Fox. *Mem.*, LIX, 200 (1934).

[2] *Gen. Rep. Rec.*, 72, 87 (1937).

[3] *Mem.*, VII, 187 (1871).

[4] R. W. Palmer. *Rec.*, LV, 158 (1923).

[5] *Gen. Rep. Rec.*, 72, 88 (1937).

In places, strong dykes of the trap, with transverse prismatic structure, traverse the main mass and seem to penetrate the gneiss for short distances.

It has been suggested that the Sylhet Trap is represented by dykes of a fine-grained, compact trap, generally distributed in the Garo Hills but most numerous in the northwestern portions thereof. These usually narrow intrusions are found in the gneiss, in most cases coincident or nearly so with its foliation strike, but sometimes injected horizontally along joint-planes ; they often show a well-defined columnar jointing perpendicular to the surfaces of contact.[1] Fox finds these dykes to be lithologically indistinguishable, both in hand specimens and under the microscope, from the doleritic and basaltic dykes in the Damodar valley coalfields ; if the latter, therefore, are correctly referred to the Deccan Trap, the dykes of the Garo Hills may also be of this age and not examples of the Sylhet Trap. Practically all the prehistoric stone celts, which are so common in the Garo Hills, have been fashioned out of the Sylhet doleritic basalt.[3]

KOTA AND CHIKIALA STAGES OF THE GODAVARI VALLEY.

Kota stage.—In the Godavari valley, the principal representatives of the Upper Gondwana are the Kota and Chikiala stages, the former of which was for a long time associated with the Maleri as constituting one subdivision known as the Kota-Maleri group. A more modern view is that the Kota is appreciably younger than the Maleri which has already been described. The village of Kota, after which the stage we are now to consider has been named, is situated on the left bank of the Pranhita or Wainganga, about eight miles above its junction with the Godavari, and is well known to Indian geologists by the discovery there of fossil teeth and other remains of fishes by Drs. Walker and Bell in 1841.[4] The Kota stage which overlies the Maleri, consists principally of coarse, loosely compacted sandstones with some subsidiary bands of shale, and three very prominent bands of limestone, from which the following animal remains have been obtained :

Crustacea.—
  Cyzicus [*Estheria*] *kotaensis* Jones,
  Candona kotaensis.
Insecta.—
  Undetermined blattid.[5]
Pisces.—
  Lepidotus deccanensis Egerton,
  ,, *longiceps* ,,

Pisces—*contd.*
  Lepidotus breviceps Egerton,
  ,, *pachylepis* ,,
  ,, *calcaratus* ,,
  Tetragonolepis oldhami ,,
  ,, *analis* ,,
  ,, *rugosus* ,,
  Dapedius egertoni Sykes.

Unassociated with the above fish, the following plant remains have been found in sandstone bands in different parts of the field ; though it is not certain whether in all cases these belong to the Kota or to the older Maleri subdivision, it has been claimed that they probably came from lower and not higher horizons than the fish remains, a claim which appears to be unacceptable.[6]

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[1] T.H.D. La Touche. *Rec.*, XX, 41 (1887).

[2] "*Current Science*", Mar. 1935, p. 429.

[3] *Gen. Rep. Rec.*, LXXI, 82 (1936).

[4] *Q. J. G. S.*, VII, 272 (1851) ; *Ibid.* XIX, 149 (1863) ; *Mem.*, XVIII, 125 (1881).

[5] Hislop mentions a blattid fore-wing from Kota ("Stephen Hislop, Pioneer Missionary and Naturalist in Central India". G. Smith (London ; J. Murray, 1888), p. 256.

[6] *Pal. Ind.*, Ser. II, XI & XII, Vol. I, Pt. 4, 198-199 (1879) ; *Ibid.*, Vol. II, Pt. 2, 16 (1878).

Cycadophyta.—	
Tæniopteris (*Angiopteridium*) *spatulata* (McClell.),	(Rajmahal and Jabalpur form),
Ptilophyllum acutifolium Morr.,	(Rajmahal and Jabalpur form),
Cycadites sp.	
Coniferales.—	
? *Mesembrioxylon godaverianum* Sahni,	(doubtful whether from the Maleri or Kota),
Elatocladus conferta (O. & M.),	(Rajmahal and Jabalpur form),
,, *jabalpurensis* (Feistm.),	(Jabalpur form),
Retinosporites indica (O. & M.),	(Rajmahal and Jabalpur form),
Athrotaxites feistmanteli Sahni,	
"*Cheirolepis cf. münsteri* Schenk",	(probably a *Brachyphyllum* or *Pagiophyllum*),
Araucarites cutchensis Feistm.,	(Jabalpur and Umia form),
,, *macropteris* Feistm.	

Modifying a remark by Mr. Hughes, we thus appear to have associated in the same group, plants of the Rajmahal, Jabalpur and Umia formations, occurring in what have been claimed to be lower and not higher horizons than animals which if judged by European analogy, are not younger than the Lias. The majority of the specifically determined plants are found in the Sripermatur or some of the other groups of the same age on the east coast, and the Kota flora, such as it is, is usually given a place intermediate between the Rajmahal and Jabalpur floras and would therefore appear to be in some measure coeval with the Rajmahal Trap. It may be noted that nearly all its species are found in the Jabalpur series. Until the confused stratigraphy and uncertain provenance of some of the plant remains have been elucidated, no important conclusions can be drawn from the fauna or flora of these beds.[1]

Chikiala.—Resting on the Kota beds is a group which was separated by Dr. King under the name of Chikiala, from a village of that name situated close to their boundary though built actually upon the Kota sandstones. They form the eastern margin of the Gondwana basin, extending with a width of from eight to ten miles for a distance of nearly seventy miles from a little above Rebni in the Wardha valley to the reach of the Godavari below Enchapalli. The rocks, which are unfossiliferous, consist of light brown, red, yellow and buff sandstones, and heavy bands of conglomerate of white quartz pebbles. The stage is highly ferruginous and is the local source for iron. A few clay bands and seams of shale are seen.

The junction of this stage with the Kotas is obscure, but a slight unconformity is suspected. Its lithological similarity to the Tripati sandstones of the coastal region and its superjacent position with regard to the Kota beds appeared to encourage the conclusion that the Kota-Chikiala succession was the stratigraphical equivalent of the Ragavapuram-Tripati sequence,[2] but there is little doubt that the latter is Lower Cretaceous in age. Unless the unconformity between the Kotas and Chikialas is larger than surmised, the latter may be assumed tentatively to occupy a stratigraphical level more or less equivalent to the Jabalpur group, but there is some doubt about the age of these beds.

To the Chikiala stage Hughes would refer a small thickness of beds overlying the Kotas near Balanpur, fifteen miles southeast of Jangaon ; these include a clay shale with strings of jet-like coal, and soft yellow sandstone with fragmentary carbonaceous markings.[3]

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[1] A discussion of the position will be found in Sir Cyril Fox, *Mem.*, LVIII, 136 (1931).

[2] *Mem.*, XVIII, 290 (1881).

[3] *Rec.*, XI, 30 (1878).

JABALPŪR SERIES.

Satpura region.—Overlying the Mahadevas of central India is a series named after the military cantonment of Jubbulpur but spelt in the modern fashion, Jabalpur, the beds of which have been recognised at intervals from southern Rewah westwards along the southern side of the Narbada valley, and are seen capping the northern hills of the Satpura.[1] It has been suggested that the lower portion of these beds should be separated off from the rest as the Chaugan stage, and that the Umia plant beds of Cutch should be associated with the Jabalpurs on account of the prominence therein of the newer conifers and absence of the large Rajmahal cycad fronds in both these floras. According to this scheme, the Jabalpur series would consist of a basal Chaugan stage, a middle Jabalpur stage, and an upper Umia stage. The palæontological individuality of the Chaugan beds, which are lithologically very similar to the rest of the Jabalpurs, is not well marked, however, while the Umia beds are considerably distant from the type area of the Jabalpurs. In this work, it is proposed to describe the Chaugan beds and the so-called Jabalpur stage as one formation, *viz.*, the Jabalpur series, occurring between the Mahadevas and Lametas in the type area at both ends of the Mahadeo hills and in the vicinity of Jabalpur, and to treat the Umia group as an independent member of the Upper Gondwana in stratigraphical succession to the Jabalpur.

In the Sitariva valley of the Satpura region, the Jabalpur beds are said to pass down with apparent conformability into the Bagra-Denwa stage, the presumed equivalent of the Rajmahal traps and plant beds ; to the west, in the Dudhi valley, the boundary between the two is described as often difficult to define.[2] In other parts of the Satpura region, there is a visible unconformity and a marked overlap at the base of the Jabalpurs, which can be seen resting successively upon the Bagras, Denwas, Pachmarhis, Bijoris and gneiss. The Jabalpurs are overlain either by the Lametas or by the Deccan Trap. In the former case, there is again no sign of unconformity, although the flora of the Lametas, as compared with that of the Jabalpurs, indicates a break of considerable size ; with the Deccan traps an unconformable junction is sometimes seen. Most probably the Jabalpur beds were at one time completely covered by the Deccan Trap and Lametas. The thickness of the Jabalpurs along their junction with the Trap has not been measured, nor has it been determined elsewhere with any accuracy ; it is, however, of no great extent, so far as is known, and the total thickness of the series nowhere exceeds 1,000 feet. In the Mahadeo hills, the beds are believed to thin out rapidly southwards.

The Jabalpur beds, the highest Gondwana strata exposed in the Mahadeo hills, consist of massive sandstones alternating with soft white clays ; the latter are unique in the Gondwana succession and by their presence the Jabalpur formation can often be identified. In addition, subordinate beds of conglomerate, earthly hæmatite, coal, carbonaceous shale, red clay, and chert may occur. The sandstones differ little from the Pachmarhi sandstones except that they are finer, softer and less uniformly pebbly.[3] Pebbles are mostly concentrated in regular conglomerates which, on the whole, are finer and more sandy than those in the Bagra beds, and are distinguishable by the numerous pebbles of jasper, in this respect forming a contrast to the Pachmarhi conglomerates with their pebbles of white quartz. A coarse variety of the sandstone, compacted almost to a quartzite, is frequently found at the base of the formation where it overlaps the Mahadevas on to gneissic rocks. This basal bed is often conglomeratic, the matrix round the pebbles consisting of white earthy rock in a porcelanic condition ; in rare cases the bed is calcareous. Unlike other Gondwana sandstones, those of the Jabalpur series frequently contain fossil plants, mostly in the form of structureless branchlets. Some of the white clay is of a refractory quality and suitable for the manufacture of fire-bricks, tiles, pipes and similar articles.[1]

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[1] C. S. Fox. *Mem.*, LVIII, 113 (1931).
[2] *Ibid.* LVIII, 115 (1931).
[3] H. Crookshank. *Mem.*, LXVI, 242 (1936).

The bands of jet coal, very different in character from the coal of the Damuda formation, are never more than a few inches thick and are very impure. The earthy hæmatite is disseminated along certain of the bedding planes, in the form of nodules which in places combine to form lenticular patches sometimes as much as sixty feet in length and a foot or more thick ; the nodules are the principal source of the fossil plants. Red clays are uncommon but not absent. Cherty beds are abundant locally and are found full of plant stems in an erect position. The silica of these beds was in all probability derived from the overlying traps and was largely responsible for the preservation of so many plants. The Sher river section (Chaugan) includes some bands of dolomitic limestone.

The small outcrop of this formation around the station of Jubbulpore consists of thick, soft, yellow, brown or white sandstones, passing up into a conspicuously white or pale-tinted succession of fire-clays and soft shales with subordinate bands of sandstone. The sandstones of the lower part of the exposure are current-bedded or irregularly bedded, usually free from pebbles but locally conglomeratic near the boundary with the underlying Archæan floor ; the trace of this boundary is a very tortuous one. In a well in the old jail compound, a seam of coal was encountered at a depth of 70 feet, at or near the base of the series ; this coal crops out in a small exposure in the Narbada river-course, where it can be seen resting upon a steep edge of the Archæan.

The Jabalpur flora consists of the following forms, including a few doubtful determinations :[2]

Filicales.—	
Coniopteris hymenophylloides Brongn.,	Common ; a Rajmahal form.
Gleichenites rewahensis Feistm.,	
Sphenopteris (*Dicksonia*) *hughesi* Feistm.,	Common ; a Raniganj and Bijori species.
Alethopteris [? *Caldophlebis*] *medlicottiana* Oldh.,	Common.
Cladophlebis (*Eboracea*) *lobifolia* (Phill.),	Common.
,, *denticulata* Brongn.,	Common ; a Rajmahal and Umia form.
Hausmannia dichotoma Dunk.,	
,, *buchii* Andreæ.,	
? *Haydenia thyrsopteroides* Sew.,	An Afghanistan form.
Cycadophyta..—	
Dictyozamites indicus Feistm.,	Rajmahal form.
Tæniopteris sp.,	Probably a Rajmahal species.
,, (*Oleandridium*) *vittata* Brongn.,	Locally abundant ; a cycad with a dichasial habit, found in the English Jurassic and very frequently associated with the flower known as *Williamsoniella ;* an Umia form, and found also in the Lower Jurassic of Argentine.

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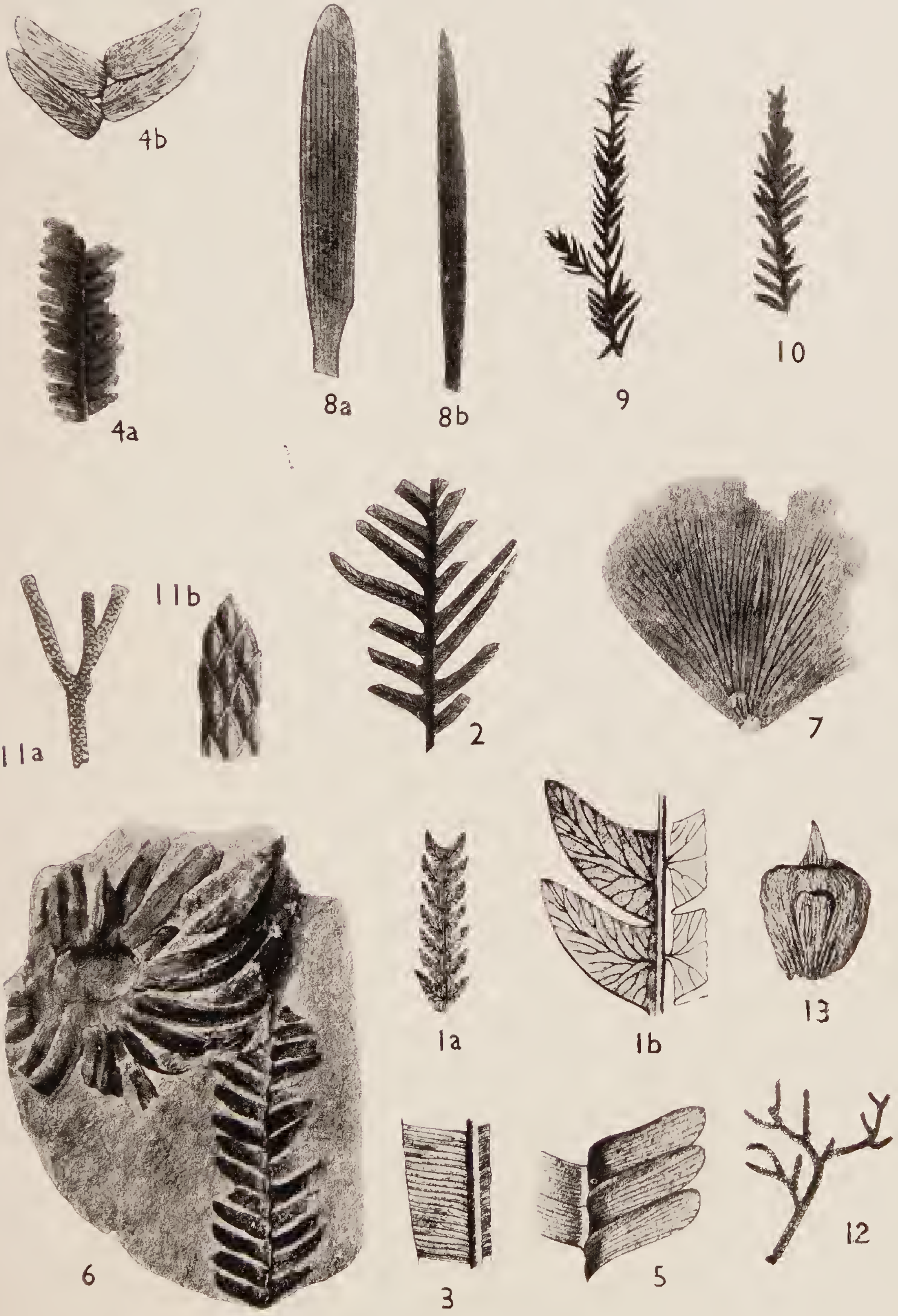
[1] *Gen. Rep. Rec.*, LXII, 34 (1929).

[2] Modified from Dr. Crookshank's list. *Mem.*, LXVI, 251-253 (1936). Writing in 1922, Professor. B. Sahni contented himself with mentioning only 15 Jabalpur plant fossils, one with a query. The flora, like that of the Rajmahal series, is in need of re-examination.



JABALPUR AND UMIA FLORAE.

1. (a,b). *Cladophlebis denticulata* (Brongn). 2. *C. medlicottiana* (Oldh). 3. *Taeniopteris vittata* (Brong). 4. (a,b). *Ptilophyllum acutifolium* Morr. 5. *P. cutchense* McCl. 6. *Williamsonia blanfordi* Feistm. 7. *Ginkgoites lobata* Feistm. 8. (a,b). *Desmiophyllum indicum* Sahni. 9. *Elatocladus jabalpurensis* (Feistm). 10. *E. indica* (Oldh). 11. (a,b). *Brachyphyllum mamillare* Brong. 12. *B. expansum* (Sternb). 13. *Araucarites cutchensis* Feistm.

G. S. I., Calcutta.

Tæniopteris sp.	
,, (*Macrotæniopteris*) *crassinervis* (Feistm.),	Locally abundant ; a Rajmahal form.
,, (*Angiopteridium*) *spatulata* (Mc Clell.),	,, ,, ,, ,,
Anomozamites cf. *nilssonea*	,, ,, ,, ,,
Nilssonia princeps (O. & M.),	,, ,, ,, ,,
,, *orientalis* (Heer),	,, ,, ,, ,,
,, *compta* (Phill.),	,, ,, ,, ,,
,, *rajmahalensis* (Morr.),	,, ,, ,, ,,
Otozamites hislopi Oldh.,	
"*Pterophyllum nerbuddaicum* Feistm.",	Probably *Ptilophyllum acutifolium* Morr.
Williamsonia indica Sew.,	A Rajmahal form.
Ptilophyllum acutifolium (Morr.),	Very common ; has a wide range ; Rajmahal and Umia form.
Ptilophyllum cutchense Morr.,	A Rajmahal form.
Cycadites cf. *gramineus*	
Coniferales.,	
Elatocladus tenerrima (Feistm.),	Rajmahal and Umia form.
,, *plana* (Feistm.),	Found also in the Jurassic of new South Wales and Queensland, and in the Lower cretaceous of Queensland.
,, *conferta* (Feistm.),	Rajmahal form.
,, *jabalpurensis* (Feistm.),	Found also in the Jurassic of Argentina.
Retinosporites indica (O. & M.),	Common ; Rajmahal and Umia form.
Brachyphyllum mamillare Brongn.,	Common ; Rajmahal form.
,, *feistmanteli* (Hazze.),	
,, (*Echinostrobus*) *rhombicum* (Feistm.) ;	
,, (,,) *expansum* (Sternb.)	Rajmahal and Umia form.
,, (,,) var. *indica* Sahni,	
Pagiophyllum ("*Pachyphyllum*") *peregrinum* (L. and H.)	Common ; probably a Rajmahal form ; found also in the Jurassic of New Zealand.
,, *divaricatum* (Bunb.),	Umia form.
Strobilites sewardi Sahni,	Probably the megastrobilus of *Elatocladus jabalpurensis*.[1]
Araucarities cutchensis Feistm.,	Common ; an Umia form ; found also in the Jurassic of New South Wales, New Zealand and Antarctica.
,, *latifolius* Feistm.,	
,, *macropterus* Feistm.,	
Conites sp., cf. *Strobilus anceps* Berry.,	
Ginkgoales.—	
Czekanowskia sp.,	
Ginkgoites lobata (Feistm.).,	
Incertae sedis.—	
Desmiophyllum indicum Sahni,	Very common ; "*Podozamites lanceolatus* L. & H."

In comparing this flora with the floras of Rajmahal, Umia and the East Coast beds, it will be seen that 19 or 20 of the Rajmahal, 8 of the Umia, and 14 of the Ragavapuram-Vemavaram-Sripermatur species are found in the Jabalpur series. At the same time, the Rajmahal flora comprises more than twice as many determined species as the Umia flora, and the Jabalpur beds are distinguished by a conspicuous absence of many of the commonest and most characteristic Rajmahal plants. The Jabalpur series has usually been regarded as representing a period intermediate between the Rajmahal series and the Umia plant beds of Cutch. *Hausmannia*, a genus common in the Jurassic floras of Europe, has only recently been found in India ; it has been discovered in the Upper Gondwanas of the Antarctic and in the Esk series (Upper Trias) of Queensland. Most of the Jabalpur species have a wide stratigraphical range. The facts that *Dictyozamites* is a genus specially characteristic of the Middle Jurassic, and that other genera, notably *Nilssonia*, *Tæniopteris* and *Pterophyllum* are rare in higher horizons, have been advanced as reasons for assigning the Jabalpur series to a position not younger than Middle Jurassic ; generally speaking, they have every appearance of straddling a higher section of the Jurassic than the Rajmahal Plant Beds and than the Kota stage. For the present, they may be accepted as belonging for the most part to the Upper Jurassic.[1]

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[1] B. Sahni. *Pal. Ind.*, New Ser., XI, Pt. 1, 41 (1928).

South Rewah and Korea.—Strata with a Jabalpur type of flora occur in south Rewah, near Chandia, northwest of Umaria. The succession, which is overlain by Lameta deposits, includes the beds of white clay so typical of the Jabalpur series : the twelve or thirteen plants remaining are all Jabalpur forms.[2] Rocks of a similar kind but lacking the evidence of fossils are found in the highlands of Korea, one of the Tributary States of the Central Provinces.[3]

Kathiawar.—To the east of Cutch, on the other side of the Rann, the Upper Gondwanas have been recognised in Kathiawar, where they occupy about 1,500 square miles in the north of the peninsula, including the capital city of Dhrangadhra. The aggregate thickness of these beds, exposed near Than, is not more than 1,500 feet; their base is not exposed and they are overlain by the Wadhwan Sandstones which are thought to be lowermost Cretaceous in age. The Than beds consist for the most part of imperfectly cemented sandstones, unevenly stratified, with coarse, gritty or conglomeratic layers ; oblique lamination is very prevalent and ripple-marking frequent. Among these strata are some thick beds of fine texture and a few subordinate bands of shale ; an ironstone band has in the past been smelted for iron.[4] One of the sandstones near the top is sufficiently hard and quartzitic to be used for quernstones. From a carbonaceous variety of the shale, in the neighbourhood of the village of Than, the following fossil plants have been obtained :

Filicales.—
(U) (J) *Cladophlebis denticulata* Brongn., (also found in the Rajmahal),
Pecopteris sp. ;
Cycadophyta—
Tœniopteris spδ ;
(U) *Ptilophyllum cutchense* Morr., (also found in the Rajmahal).
Coniferales.—
(J) *Elatocladus jabalpurensis* (Feistm.)δ;
(U) (J) ,, *tenerrima* (Feistm.) (also found in the Rajmahal).
(U) (J) *Brachyphyllum* (*Echinostrobus*) *expansum* (Sternb.) (also found in the Rajmahal),
(U) (J) *Araucarites cutchensis* Feistm.,
Incertae sedis.—
(J) *Desmiophyllum indicum* Sahni.[5]

These Kathiawar beds were equated with the Umia plant stage in Cutch, and the lithological resemblance and geographical proximity seemed to favour such a correlation, but since all specifically determinable plants but one in the shales of Than are members of the Jabalpur flora, the beds have every appearance of belonging to the latter series; the exception is *Ptilophyllum cutchense*, the presence of which is no determining factor since this form is found in the Rajmahal series. Seward makes no distinction between *P. cutchense* and *P. acutifolium*, which is found not only in the Jabalpur series, but also in the Rajmahal and the Umia plant beds.

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[1] B. Sahni. *Pal. Ind.*, New Ser., XI, Pt. II, 99,107 (1931).

[2] O. Feistmantel. *Rec.*, XIII, 189 (1880) ; T. W. H. Hughes *Ibid.* XIV, 319 (1881) ; F. R. Mallet *ibid.* 142 (1889).

[3] C. S. Fox. *Mem.*. LVIII, 8 (1931).

[4] F. Fedden. *Mem.*, XXI, Pt. II, 9 (1884).

[5] "*Podozamites lanceolatus* L. and H.", probably the equivalent of Sahni's *Desmiophyllum indicum*. *Podozamites lanceolatus* is recorded from the Lower Jurassic of New South Wales, and the Lower Cretaceous of Queensland, so that, even when rightly identified, it is of limited stratigraphical significance. Forms so described originally from the Jabalpur and Kota formations are, according to Sahni, doubtfully referable to *Podozamites* (*Pal. Ind.*, New Ser., Vol. XI. Pt. 1, 10 (1928).

NARHA BEDS OF CUTCH.

In the rocks of Cutch, near a village named Narha in the northern part of the State, a few plant remains have been found at an horizon lower than that of the Umia plant beds. These Narha beds have yielded cephalopods believed to be intermediate in the age between those of the Upper Katrol and the marine Umia beds and assigned to the Lower Portlandian.[1] The succession consists of dark shales and flags underlain and overlain by sandstones. The cephalopods were collected from some of these sandstones. The fragmental plants were found at one place in the dark shales, here about 5 feet thick, and among them the following species have been determined :

Filicales.—	
? *Coniopteris hymenophylloides* Brongn.,	("*Sphenopteris* cf. *arguta* L. & H.").
Cladophlebis denticulata Brongn.,	("*Alethopteris whitbyensis* Feistm.").
Cycadophyta.—	
Otozamites cf. *contiguus* Feistm.,	(*O. contiguus* Feistm. is probably identical with *O. bengalensis* Morr.).
Coniferales.—	
Araucarites cutchensis Feistm.,	

The three last are apparently identical with species found in the Umia bed higher up, whilst *Coniopteris hymenophylloides* is an English Lower Oolite species found also in the Jabalpur and Rajmahal series ; *Cladophlebis* and *Arqucarites* are also Jabalpur forms. The connection of the Narha flora with that of the Jabalpur series is just as strong as with that of the Umia series. The Narha beds so far as their limited flora can be relied on, would thus appear to occupy a position intermediate between these two series, and to confirm the idea that the Umia plant beds are younger than the Jabalpur. Such a scheme would make the Narha beds equivalent in age to the lower or marine subdivision of the Umia series.

UMIA PLANT BEDS OF CUTCH.

The name, Umia, has been applied to some 3,000 feet of sandstones and shales in the small peninsula of Cutch (Kachh), and is derived from a village about fifty miles northwest of Bhuj, the chief town of Cutch. The Umia series is divisible into two stages, consisting of a basal calcareous conglomerate with marine fossils, and an upper stage characterised by terrestrial plant fossils and a *Trigonia* bed. The lower stage with its Upper Portlandian or Lower Tithonian ammonite fauna overlies older Jurassic marine strata (Katrol). The upper stage, with which we are now concerned, is usually overlain unconformably by the Deccan Trap except at Ukra Hill where marine beds of Aptian age follow it.

The purely marine lower stage of the Umia series will be described under the heading of Jurassic (p. 1152). The special interest of the upper stage, in connection with the formations considered in this chapter, lies in the fact that it includes beds containing plants, several of which are identical with those of the Jabalpur beds, interstratified with rocks yielding marine fossils. These Upper Gondwana Umia beds are largely concealed by a thick soil-cap and in the north by alluvial sediments. Clay and shale, as shown by bore holes, constitute a considerable proportion of the sequence, though surface exposures are mostly of sandstones. The latter are strongly current-bedded and vary from thick massive beds through flag-stones to thin-bedded argillaceous varieties and sandy shales. They show all degrees of coarseness from very fine-grained rocks quarried for grindstones to grit-stones; conglomerates are rare. Dunn notes that some of the sandstones are quite white, while others are so ferruginous that they were utilized at one time for local iron smelting. In the vicinity of trap dykes, the sandstones have been hardened to quartzites. A friable white fine-grained sandstone near Morvi is used for the manufacture of glass. Some of the sandstones underground furnish useful quantities of water, some of which, however, is brackish. A few of the clays and shales are of a brilliant colour and have been used for making pigment. The white clays grade to black carbonaceous varieties with thin bands of high-ash coal; locally, clays are employed in the manufacture of stoneware jars and pipes, or, when sufficiently refractory, for fire-bricks. Several borings for coal have been made but with no encouraging results.[1] A 16-inch seam of coal crops out about six miles northeast of Bhuj, but only some eight inches are of good quality.[2]

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[1] L. F. Spath. *Pal. Ind.*, New Ser., IX, *Mem.*, 2, Pt. VI. 797 and 868 (1933) ; A.B. Wynne. *Mem.*, IX, 213 (1872).

The following is a list of the plants from the Umia beds, all the conifers being Jabalpur species :—

Filicales—	
Cladophlebis denticulata Brongn.,	A Jabalpur form.
Gleichenites (?) sp.,	
Pachypteris sp.,	
Actinopteris sp.,	
Cycadophyta—	
Tæniopteris (*Oleandridium*) *vittata* Brongn.,	Found also in the Jurassic of Argentina and New Zealand. Probably the fronds of the plant bearing the flowers known as *Williamsoniella*.
Ptilophyllum acutifolium Morr.,	A Rajmahal and Jabalpur form; including *P. brachyphyllum* Feistm.
,, *cutchense* Morr.,	A Rajmahal and Jabalpur form.
Otozamites bengalensis (Morr.),	A Rajmahal form.
Cycadites cutchensis Feistm.,	
Cycadolepis pilosa Feistm.,	Perhaps the bracts of *Williamsonia* flowers.
Coniferales—	
Retinosporites ("*Palissya*") *indica* (O. & M.),	A Rajmahal and Jabalpur form; including "*Palissya bhoojoorensis* Feistm.", "*P.* cf. *indica* Feistm." and "*P.* cf. *laxa* (Phil.)."
Pagiophyllum cf. *divaricatum* (Bunb.),	A Jabalpur form.
Brachyphyllum (*Echinostrobus*) *expansum* (Sternb.).,	A Jabalpur form.
Araucarites cutchensis Feistm.,	A Jabalpur form, found also in the Jurassic of New South Wales, New Zealand and Antarctica.
,, *macropterus* Feistm.,	A Jabalpur form.
Elatocladus tenerrima (Feistm.),	A Rajmahal and Jabalpur form.
Conites sp. *a*.	

The Umia series would appear to straddle the uppermost Jurassic and lowermost Cretaceous, the ammonite bed at the base being either Upper Portlandian or Lower Tithonian, and the plant beds Upper Tithonian or basal Cretaceous or both.

AHMEDNAGAR SANDSTONE OF IDAR.

The Ahmednagar Sandstone of Idar State was provisionally assigned by Middlemiss to the Cretaceous. This assignment has since been justified by the discovery of determinable plant remains in a coarse, ferruginous rock, belonging to the formation and cropping out some two miles north of Ahmednagar (Himatnagar) town. Two genera of xerophytic ferns have been recognised by Dr. B. Sahni, who describes two species, one of them new, under the names of *Matoni-*

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[1] J. A. Dunn. *Rec.*, LXXVII, Prof. Paper No. 5 (1942).

[2] A. B. Wynne. *Mem.*, IX, 166 (1872).

dium indicum Sahni and *Weichselia reticulata* (?) Edw.[1] The former is closely allied to *M. goepperti* Schenk, which ranges from the Inferior Oolite to the Wealden in Europe, while *Weichselia reticulata* has not so far been found outside the Cretaceous and is a leading Wealden species, found in Europe, North Africa, Syria, America and the Far East. The presence of the latter plant suggests definitely a Wealden age for the Ahmednagar Sandstone.

This almost undisturbed and nearly horizontal formation, of which only about 100-200 feet are exposed, consists of conglomerate, a large proportion of sandstone, and shales. The beds are well seen in the Hathmati river section near the capital town of Ahmednagar, and are exposed in a few low hillocks near by and in the Sabarmati river bed for several miles along the Idar-Baroda boundary. Their most characteristic occurrences are seen in a series of low plateaux with steep scarped edges to the east of Ahmednagar, where the beds lie with a pronounced unconformity on the Erinpura Granite or the Aravalli quartzites and gneisses.

The prevailing rock type is a sandstone, white with pinkish markings[2] and streaks, and with occasional ferruginous concretions of the size of an egg ; generally it is fine in grain and somewhat loosely aggregated, but coarser millstone-grit varieties are sometimes found.[3] The cementing material is siliceous and ferruginous ; in places this has given rise to a glassy quartzite, quartzitic sandstone or conglomerate, but the more or less rounded grains of quartz always maintain their individuality and the bedding is invariably distinct. Current-bedding is common and the beds are traversed by strings and veins of calcite. In the sandstones are many layers of shale and mottled pink and white lithomarge. Limonite occurs among the shales, conglomerates and gritty layers, at several places. The lower portion of the formation is conglomeratic, but the base where it rests on the granite consists locally of layers of kaolin, probably representing the old surface alteration of the granite preserved from removal by the capping of hard sandstone. Several of the sandstone layers, especially those which are pale in colour, make an excellent freestone and are much quarried for architectural and engineering purposes.

Katkot Sandstones of the middle Narbada.—Around the town of Barwai, on the north bank of the Narbada on the borders of the Dhar forest in Indore, occur some thick-bedded, rather soft, whitish sandstones which show a strong resemblance to Mahadeva rocks and, like them, contain no fossils except fragments of drift wood which are locally plentiful. They are overlain by the Deccan Trap, but in one or two cases there intervenes an oyster bed of Upper Cretaceous (Bagh) age.[4] In another tiny inlier, E.S.E. of Barwai, the sandstone is separated from the overlying Trap by Lameta beds with fresh-water shells; there is no apparent discordance between the sandstones and the Lameta beds. North of Barwai, around the village of Katkot, is a much larger outcrop composed of about 8 feet of fine-grained, shaly beds, red, pink or mottled, with ferruginous or carbonaceous concretions; at Katkot itself, these beds pass into conglomerates and sandstones indistinguishable from the beds around Barwai. Two miles east of the village this sandstone has been quarried since remote antiquity.[1] Northwards, the Katkot sandstones thin out and the beds become reduced to a band of conglomerate, which reappears in two additional outcrops further north and north-east, along the margin of the Trap which overlies it: in these outcrops the conglomerate is accompanied by a few feet of superposed fine-grained rocks.

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[1] *Rec.* 152-160 (1936).

[2] B. C. Gupta and P. N. Mukherjee. *Rec.* 71-73, 192(1938).

[3] C. S. Middlemiss. *Mem.* XLIV, 137-142 (1921).

[4] This is the description of older writers. The exceptional occurrence of marine Cretaceous fossils recorded by Vredenburg in the basal conglomerate near Barwai is difficult to reconcile with the fresh-water aspect of the rest of the beds, especially the Nimar sandstone (*Gen. Rep.*, 1902-3, p. 20). Mr. Vredenburg's later conclusion was that the Katkot sandstone was itself part of the Bagh sequence. For this reason the Katkot and Nimar sandstones have been spoken of as members of the Bagh series. The whole question requires revision, but the provisional solution adopted in this work is that the Katkot and Nimar sandstones are mutually equivalent, and older—probably considerably older—than the Bagh beds, though not as old as the Mahadeva. They have much in common with the Ahmednagar Sandstone which as we have seen is basal Cretaceous, and there seems to be no serious objection to associating the three formations.

In most cases, the beds described lie upon Bijawars, but in one or two sections they rest upon Upper Vindhyan sandstone. They have been referred tentatively by some to the Mahadevas, but they occupy much the same stratigraphical position as the Nimar Sandstone, a deposit which makes its appearance further west and is described below. The Katkot beds have every appearance of being fresh-water deposits of Upper Gondwana aspect.

Nimar Sandstone of the Lower Narbada.—West of the Barwai area, which has just been considered, the Nimar beds crop out from beneath the Deccan Trap around Balwari (Bulwaree) and Bagh and a little more extensively to the south of Rajpur. Sometimes they form just a few feet of coarse sandstone between the Bagh limestone stage above and the metamorphics below; at other times, as up the Man river, they are wanting and the limestones repose directly on the metamorphic schists. At the junction of the Man with the Sukar, they are not more than 15 feet thick; south and southwest of Bagh they increase to 80 feet or more, while further west, near Ali the stage is 400 or 500 feet thick, with massive conglomerates at the base. South-east of Pawagarh Hill, the formation is almost horizontal and is composed of pinkish gritty sandstone with porcellanic jasperoid rock, associated with ferruginous conglomeratic beds containing pebbles of quartz and chalcedony.[2] Here the beds lie unconformably upon the Aravalli schists and phyllites and are overlain by the Deccan Trap. The sandstone has been extensively used as a building stone, especially in the old ruined city of Champaner. Small patchy outcrops of the gritty sandstones and conglomerate beds also occur to the north of Bhamria. In Rajpipla State, not very far from the mouth of the Narbada, superb sections of the sandstone are seen, some of them 800 feet high, and the total thickness must be several thousands of feet.[3] Here the beds show a noticeable disturbance and have been considerably altered to quartzitic varieties and quartzites by the numerous intrusions of Deccan Trap which intersect them throughout. In the more easterly exposures, the beds are less intruded and are approximately horizontal, though local dips of 15° or 20° are recorded; these dips appear to be due to local disturbance during the interval between the deposition of the Upper Cretaceous (Bagh) limestones and the outpouring of the Deccan Trap. Faulting is not infrequently seen.

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[1] P. N. Bose. *Mem.* XXI, 21 (1884).

[2] B. C. Gupta and P. N. Mukerjee. *Rec.* 73, 198 (1938).

[3] P. N. Bose. *Rec.* XXXVII, 171 (1908).

In the easterly sections, the Nimar stage has the appearance of being the relics of deposits laid down in old Cretaceous valleys, a deduction not incompatible with the enormous increase in thickness from east to west. The basal beds of the sandstone stage in the eastern region are described as massive and invariably conglomeratic. The conglomerates, which are of all degrees of coarseness, are made up of well-rounded pebbles embedded in a matrix of clay or sand, either loose or cemented by calcite or oxides of iron or manganese. These are succeeded by grits and sandstones, with variously coloured, interbedded, friable, shaly and marly strata. The beds are frequently calcareous or ferruginous. Current-bedding is especially characteristic of the shaly and marly beds, and is well seen on the pillars and walls of the celebrated Bagh caves. The only evidence of organic life, beside the fossil wood, is the presence of trails of arthropods and worms, impressions of minute bivalves, and some indeterminable fragments of bone.

Wadhwan Sandstone of Kathiawar.—In Kathiawar, a series of sandstones capped by some insignificant bands of limestone is found intervening between the Than plant beds below and the Deccan Trap above. The limestone probably belongs to the Upper Cretaceous (Bagh). The lower group or Wadhwan sandstone consists of brick red or dull reddish brown sandstone, more or less impure and frequently unsorted, with some argillaceous beds. The ingredients of the sandstone are for the most part indifferently cemented, though sometimes locally indurated to a quartzitic rock; in the vicinity of Wadhwan it displays local aggregations of small quartz pebbles, as well as ferruginous nodules. In the majority of sections there is little departure from horizontality, but in parts of the Wadhwan district there are local dips of 60° or more due, it has been suggested, to the ploughing up of the beds while yet unconsolidated by fissure eruptions of the basic Deccan lava. In the Morvi State, to the west, the trap can be seen in some sections banked up against steep slopes of the sandstone and had evidently found its way along valleys eroded therein. If the report of inhabitants can be accepted, a well of 50 cubits pierced no other kind of rock than the Wadhwan sandstone, but there appears to be no reason for assuming that the Wadhwan sandstone attains any substantial thickness.[1]

Probably of much the same age as the Wadhwan sandstone is a freestone which is quarried in the neighbourhood of Dhrangadhra, in the northeast of Kathiawar. It is a light-coloured, very current-bedded, kaolinised sandstone, varying rapidly in texture from a fine-grained to a coarse, gritty rock, and in colour from white to pale pink or yellow; this stone has been employed in the construction of the palace of the Rao of Cutch at Bhuj.[2]

Not only is it probable that the Wadhwan sandstone and Dhrangadhra freestone of Kathiawar, as well as the Songir sandstone of Baroda,[3] the Nimar sandstone of Gujarat and the Ahmednagar sandstone of Idar, are all part of the Upper Gondwana sequence, but it is also possible that they all belong to the same part of that sequence and are of Wealden age. The Ahmednagar Sandstone has been recognised as such in the country south of Idar.

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[1] F. Fedden. *Mem.* XXI, Pt. 2, 13, (1884).

[2] *Ibid.*, p. 63.

[3] V. S. Sambasiva Iyer. "A sketch of the Mineral Resources of the Baroda State," p. 90.

UPPER GONDWANAS OF THE EAST COAST.

Coastal character.—The Upper Gondwanas, though the term may not be strictly applicable in all cases, are represented along the east coast of India by a series of small exposures, many of them in the form of outliers on the gneiss or inliers in Pleistocene or Recent alluvial deposits, a few of them occurring between the gneiss and marine Upper Cretaceous beds ; many of these exposures are too small to deserve individual notice. They are of great interest, however, in that some of them contain marine fossils associated with the plants. The bulk of the beds have a very low inclination, though dips up-to 40° have been noted in the more southerly outcrops around Sripermatur and in Trichinopoly. Wherever their base is visible, these patches of Upper Gondwanas are seen to rest upon a floor of gneiss which has every appearance of being a plane of marine denudation. In many places their total thickness is difficult or impossible to estimate, but is never more than a few hundred feet.

Distribution.—These particular deposits are exposed in groups of small patches and have been subdivided and named, from north to south as follows :—

Cuttack area.	Ellore or Rajahmundry area (Kistna and Godavari districts).	Ongole area (Nellore and Guntur districts).	Madras area (Chingleput district).	Trichinopoly area.
	Tripati sandstone.	Pavulur sandstone.	Sattavedu beds.	...
	Ragavapuram shales.	Vemavaram shales.	Sripermatur beds.	? Utatur Plant beds.
	? Golapilli sandstone.	Budavada sandstone.	...	...
Athgarh sandstone.	? Golapilli sandstone.	...	...	? Utatur Plant beds.

Most of the subdivisions enumerated above were found to contain impressions of plants, the majority of which could be matched in the flora of the Rajmahal hills of Bengal, and by all early observers the East Coast beds were freely spoken of as Rajmahal, in spite of the fact that they contain little or no carbonaceous matter and no bedded traps. It was, at the same time admitted that the flora of the Ragavapuram, Vemavaram, Sripermatur and Utatur Plant subdivisions included a few species allied to Jabalpur forms, and appeared to be younger not only than the Golapilli flora but also than the flora of the Rajmahal hills. It was ultimately suggested that the beds containing this flora should be placed in a stage of their own—equated with the "Kota stage" of the Godavari valley—intervening between the Rajmahal Plant beds below and the Jabalpurs above. This simple scheme of classification, however, conflicts with the evidence of ammonites which accompany the plant remains in some of the deposits and have been recognised as of Lower Cretaceous age. This anomaly of beds containing both Middle Jurassic plants and Lower Cretaceous ammonites will be referred to in the sequel.

Athgarh sandstone of Cuttack.—The most northerly of the East Coast exposures, named after the village of Athgarh (Atgar), is a tract mainly of low sandstone hills covered with a dense thorny jungle ; the outcrop, some twenty miles long from north to south and eighteen miles wide from east to west, is situated to the west and southwest of the town of Cuttack, and occupies the western margin of the alluvial plain of the Mahanadi on both banks of that river. The rocks are nearly horizontal but appear to have a slight general inclination towards the southeast. A basalt dyke is recorded in these beds near Sideshar Hill. Some carbonaceous shale, occurring among the lower beds of the sandstone, has been supposed to indicate the presence of Barakar beds, and coal has been reported in the vicinity of Sideshar Hill; no Damuda fossils, however, have been found. The relations of the remaining rocks, which comprise sandstones, grits and conglomerates, with white or pinkish clay beds, are obscure, but the base or at any rate the lowest exposed section appears to consist of coarse, loose-textured conglomerates and ferruginous sandstones, while the light-coloured clay beds occur towards the top; the discovery in the latter of a few characteristic fossil plant remains may be accepted as sufficient proof of their age.[1] The following forms have been identified :[2]

Filicales—

Cladophlebis denticulata Brongn.,
Marattiopsis (*Asplemites*) *macrocarpa* (Morr.),
Gleichenites gleichenoides (O. & M.),
Thinnfeldia sp.,
Rhizomopteris balli Feistm. (the rhizome of *Dictyophyllum*).

Coniferales—

Elatocladus conferta (O. & M.),
Retinosporites indica (O. & M.),

Of this assemblage, *Rhizomopteris balli* is the only species not definitely recognised in the Rajmahal flora (though the genus *Rhizomopteris* has recently been identified), from which it may be concluded that the Athgarh sandstone is an arenaceous equivalent of that formation or belongs perhaps to the Dubrajpur stage; it is said to resemble lithologically the Dubrajpur beds, the top of which cannot be stratigraphically much below the plant beds of the Rajmahal hills and might be expected to yield a closely allied flora.

Ellore area.—On the right bank of the Godavari, about ten miles above Rajahmundry (Rajamahendri), a well-marked belt of Upper Gondwana beds commences near Thalapudi and extends southwestwards for sixty miles to beyond Golapilli west of Ellore. The width of this belt varies from ten to fifteen miles, the rocks having a general dip towards the southeast of from 5° to 10°, and escarpments facing northwest. Throughout a considerable portion of their area the beds, which scarcely exceed 600 feet in aggregate maximum thickness, rest unconformably upon various members of the Kamthi stage, here spoken of as the Chintalpudi and Dummapett sandstones. These sandstones, the equivalents of those of Tacherla in Hyderabad, are assigned to the Kamthis on the grounds of the plant fossils, *Vertebraria*, *Glossopteris* and *Phyllotheca*, found near Kunlacheru, north of Ellore.[3] At both ends of their exposure, the Upper Gondwanas overstep the Kamthi rocks and rest upon a sloping floor of gneiss which has the appearance of being a plane of marine denudation formed after the deposition of the Kamthis, the latter resting upon a much more uneven surface of the metamorphic formations. To the southeast, the Upper Gondwana beds of the Ellore area disappear beneath the Cuddalore (Pleistocene) sandstones and the alluvial deposits of the Godavari delta, except to the west of Rajahmundry where they are covered by outliers of trap which are definitely assigned to the Deccan Trap suite, and in one place by a patch of Infra-trappean beds followed by trap.

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[1] T. Oldham. *Mem.* I, 68 (1856); W. T. Blanford. *Rec.* V, 59 (1872); V. Ball. *Ibid.* X, 63-75 (1877).

[2] O. Feistmantel. *Pal. Ind.*, Ser II, Vol. I, Pt. 3, 27—189 (1877).

[3] C. S. Fox. *Mem.* LVIII, 45 (1931).

The rocks of the Ellore area are peculiarly interesting since they comprise representatives of stages occurring above beds in which the typical Rajmahal flora is well preserved. The Upper Gondwana beds of this area have been classified by Dr. King into three subdivisions, two of sandstone with an intervening one of shale, by far the bulk of the exposures consisting of the two sandstones. The three subdivisions, which have been named as follows, are fossiliferous at rare intervals, the lower yielding only vegetable remains, the middle marine shells with a few associated plants, and the upper marine shells only :—

3. Tripati sandstone B.
2. Raghavapuram shales.
1. Golapilli sandstones.

The Golapilli sandstone group, seldom more than 300 feet at its thickest, consists of brown and red sandstones, grits and conglomerates. Near Golapillis the beds form a broad plateau which is capped by conglomerates and gravels probably belonging to the Cuddalore formation. Further northeast, on the other side of the Tammileru river, the Tripati sandstone subdivision is seen below the Cuddalores, separating these beds from the Golapillis. A little further in the same direction, the middle or Ragavapuram subdivision makes its appearance and, as a very narrow and restricted outcrop, persists for about sixteen miles, when the Tripati group again overlies the Golapillis.

From the Golapilli beds have been collected the following plant impressions, all of which, with the exception of *Araucarites macropterus* (a Jabalpur species),[1] are characteristic Rajmahal forms : [2]

Filicales—

Cladophlebis indica (O. & M.) ("*Alethopteris indica* (O. & M.)"),
Marattiopsis macrocarpa (O. & M.),
Tæniopteris (*Angiopteridium*) *ensis* Oldh.,
,, ,, *spatulata* McClell.,

Cycadophyta—

Ptilophyllum acutifolium Morr.,
,, *cutchense* Morr.,
Dictyozamites falcatus (Morr.),
Nilssonia morrisiana (Oldh.) (including "*Pterophyllum carterianum* Oldh."),
Williamsonia indica Sew. ("*W. gigas* Carr"),

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[1] The genus *Araucarites* has been recognised in the Rajmahal flora.

[2] O. Feistmantel. *Pal. Ind.*, Ser. II, Vol. 1. Pt. 3, 163-190 (1877).

Coniferales—

Elatocladus conferta (O. & M.),

Retinosporites indica (O. & M.),

Brachyphyllum expansum Sternb. ("*Cheirolepis* cf. *münsteri* Schenk"),

Araucarites macropterus Feistm. (a cone scale very like *A. cutchensis* Feistm., but larger).

Resting upon the Golapilli beds in the neighbourhood of Ellore is a thin band not more than 160 feet thick, of white and buff shales with a few intercalations of sandstone. No visible unconformity has been detected between these Ragavapuram shales, as they have been called,[1] and the Golapilli sandstones, but the marine fauna of the shales appears to indicate a gap very much larger than that shown by the differences in the flora of the two subdivisions. The presence of this break is confirmed by the considerable denudation the Golapillis have evidently suffered on the northern side of the Tammileru, for the marked reduction in thickness in this direction is not likely to have been due entirely to reduced deposition. Furthermore, the Ragavapuram group in its lithological constitution is described by King as eminently separable from the underlying sandstone subdivision, irrespective of its much smaller extent; this character or condition offers ground for the conclusion that a decided interval of time must have intervened between the deposition of the sandstone and that of the shale.

While the plants of the Golapilli sandstones, with the exception of one determined species, are all Rajmahal forms, the flora of the overlying Ragavapuram shales comprises, in addition to several forms common to the beds below, a few Jabalpur species. A list of the plants from the Ragavapuram shales will be found in the tabular statement on prepage.

At certain horizons in the Ragavapuram beds and associated with rare plant remains are some marine shells and abundant casts of the same; among them are some ammonites which, until recently, had been regarded as allied to Middle Jurassic species, the principal form to the Callovian "*Stephanoceras opis* (Sow.)" (Spath's *Subkossmatia opis* and *S. obscura*). The commonest fossil is the cast of a *Leda*, found usually in a crushed condition; in addition there have been recognised: *Pecten*, *Gervillia*, *Mytilus*, *Trigonia* (? *T. interlævigata*), *Solen*, *Tellina*, fish scales and ammonites. A re-examination of the poorly-preserved ammonites in these and the corresponding Ongole beds has led Dr. Spath to Waagen's original conclusion that the beds are Upper Neocomian (and probably Barremian) and not Jurassic. The consequences of this conclusion are discussed below.

Above the shales just noticed is another thin band of dark brown and red sandstones and conglomerates, usually ferruginous, with siliceous and argillaceous beds and bands of concretionary ironstone. Towards the bottom, the sandstones become softer and less ferruginous. The very low scarped edge crowning the southwestern slopes of the Tripati (Tripetty; Tirupati) range is made up of these Tripati sandstones, and a notable headland of them overhangs the well-known temple of Chinna Tripati, twenty-three miles northeast of Ellore.[2] On the western side of the Godawari delta, the Tripati sandstones are overlain successively by the Infra-trappean beds of Dudkur, the Deccan Trap and the Cuddalore formation. On the other side of the Godavari, somewhere below the escarpment of the small Deccan Trap outlier northeast of Rajahmundry, purple sandstones representing one of the Upper Gondwana stages—possibly the Tripati—have been encountered in road-metal pits.[1] Further in the same direction, half-a-dozen small outliers of what are believed to be representatives of this sandstone group are to be found, one of them around Jaggampet (Jaggamapeta), one near Kirlampudi, one at Ayaparaz-Kotapilli ("Iñnaparazpalayam"), another east of Gilladipad, another at Idatum, and the last a few miles east of Sriramapuram. All these outliers lie upon the gneiss and are largely covered by Recent alluvium. The maximum thickness of this group cannot be more than 150 feet, and in the main area near Ellore only some 40 feet are said to be present.

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[1] The village of Ragavapuram stands actually on the boundary line between the outcrop of the Kamthis and Golapillis.

[2] W. King. *Mem.* XVI, Pt. 3., 30-31, *Reprint* (1930). Tripati village is situated on the Ragavapuram shales.

In the main area, the Tripati beds have yielded only fossil wood, probably coniferous, but from the outlying patches at Ayaparaz-Kotapilli, twenty-four miles N.-by-E. of Coconada, believed to belong to the same band, King obtained two species of *Trigonia*—*T. smeei* Sow. and *T. ventricosa* Krauss; both these species are characteristic of the Umia beds of Cutch, the latter being found also in the Aptian beds of the same State, as well as in the Uitenhage system of South Africa. In addition, there have been collected species of *Inoceramus*, *Pseudomonotis*, *Lima* and *Pecten*, belemnites, and ammonites including the Cretaceous genus *Helicoceras*.[2] The suggested correlation of the Tripati sandstones with the Chikiala sandstones of the Pranhita-Godavari region[3] has nothing to support it unless the equivalence of the Kota and Ragavapuram stages should be established; the lithological resemblance of the two sandstone groups is by itself of little correlative value. Originally the Tripati beds were considered to be the equivalents of the upper Umia beds of Cutch (Upper Tithonian or Valanginian), apparently on account of the two species of *Trigonia*; certain forms of this genus, however, appear to have a long vertical range.[4] Assuming the Ragavapuram shales to be Upper Neocomian (Barremian), the Tripati sandstones could not be older than Barremian and might be of Aptian age.

Although the three stages of what have been called the Upper Gondwanas of this area exhibit no sign of angular unconformity, the middle one is distinctly overlapped at both ends, and its outcrop appears as a thin lenticular band incompletely separating the other two. It is clear that the country could have undergone very little disturbance in the intervals between the deposition of the different groups. Incidentally, the absence of any marked stratigraphical break in this coastal area persists after the Tripati epoch up to and including the deposition of the Cuddalore sandstones which are of Pleistocene or late Tertiary age, for there is no visible unconformity—except by overlap—between the Tripati sandstones, the Infra-trappeans, the Deccan Traps and Inter-trappeans, and the Cuddalore beds.[5]

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[1] *Gen. Rep. Rec.* XXXII, 157-158 (1905).

[2] Hurriedly determined by Dr. Stoliczka and apparently not subsequently redetermined.

[3] In C. S. Fox. *Mem.* LVIII, 233 (1931).

[4] L. F. Spath. *Pal. Ind.*, New Ser., Vol. IX, *Mem.* 2, 798 (1938); L. F. Spath. *Geol. Mag.* LXXII, 184-189 (1935).

[5] W. King. *Mem.* XVI, Pt. 3., 36, *Reprint* (1930).

Ongole area.—South of the Kistna river, Mr. Foote has recognised about two dozen small outcrops of "Upper Gondwana" beds north and south of Ongole, besides many other occurrences in wells and water-courses, too small to map. A few occur within the coastal alluvium but most of them fringe the gneissic outcrop of this area. Several hundreds of square miles of these beds are probably hidden beneath the alluvium. The sandstones in many of the exposures are quarried locally for building-stone. The "Upper Gondwanas" of the Ongole area show slight rolling but swerve little from the horizontal.

In the outcrops north of Ongole, including those southeast of the town of Guntur, Mr. Foote has detected a threefold division of the beds, which at that time was thought by others to correspond to that of the Ellore area; these three groups were distinguished as follows:

3. Pavulur sandstones.
2. Vemavaram shales.
1. Budavada sandstones.

The Budavada stage, named after the village of Budavada (Boodhawadah) and consisting chiefly of sandstones, has yielded numerous marine fossils, which do not appear ever to have been fully determined, and a few plant impressions. Both animal and plant remains come from the uppermost horizons of the subdivision. Foote's provisional field list of the former includes: *Serpula* sp., a bryozoan, *Pleuromya* ("*Myacites*") sp., *Modiola* sp., *Avicula* sp., *Plicatula* sp., *Lima* sp., *Rhynchonella* spp. (two or three), *Patella* spp. (at least three), *Natica* sp., and less certain examples of *Gresslya*, *Mactra*, *Astarte*, *Cardium*, *Trigonia*, *Yoldia*, *Pecten*, *Ostræa*, *Terebratula*, *Trochus*, *Turbo*, *Eucyclus*, *Turritella*, *Cerithium*, *Buccinum* and Ammonites.[1] The plants comprise: *Ptilophyllum acutifolium*, *Otozamites* sp., *Dictyozamites indicus*, *Tæniopteris* (*Angiopteridium*) *spatulata*, undetermined leaflets and small woody fragments. From the analogy of a tripartite division, it was at first supposed that the Budavada stage, although chiefly marine in character, was the equivalent of the Golapilli stage of Ellore. This correlation, however, cannot be accepted if the numerous plant remains of Rajmahal age in the Golapilli beds are correctly regarded as indigenous, since the cephalopoda of the Budavada indicate a Lower Cretaceous age much the same as that of the overlying Vemavaram shales.

The Vemavaram shales, named after the village of Vemavaram (Womayaveram) of light grey colour, mottled in parts, and varying in hardness, have yielded a comparatively rich flora of a type similar to that of the Ragavapuram stage of Ellore and the Sripermatur stage of the Madras area, but nearly all specimens were obtained from one mass of the rock which was unusually clayey in character. To avoid needless repetition and to exhibit more clearly the relationships of the floras of these groups, their plant fossils have been combined in the adjoining tabular statement, from which it will be seen that nearly half of the Ragavapuram species are found also in the Vemavaram beds, and that in each case the relationship to the Rajmahal and Jabalpur floras is very similar. Besides the plant remains, the following animal fossils were provisionally determined by Foote: *Ophiura* spp. (two), *Eschara* sp., *Terebratula* sp., *Lithophagus* [*Lithodomus*] sp., *Yoldia* spp. (two or three), *Tellina* spp. (two or three), *Leda* spp. (two or three), *Exogyra* sp., *Pecten* sp., *Inoceramus* sp., a gastropod impression *Belemnoteuthis* cf. *conotheca*, ammonites, fish scales, and a doubtful impression of a rib (?mammalian).[1] Another Vemavaram fossil is a macrurous crustacean which was thought to be closely allied to if not identical with the Liassic *Eryon barrovensis* McCoy.[2] A recent examination of the ammonites from these and other East Coast Gondwana beds has led Dr. Spath to refer them to the Lower Cretaceous instead of to the Jurassic. The two classes of organisms, plants and animals, constantly occur together in the same hand specimens. The vegetable remains are all fragmentary but show no signs of decay. Many of the shells have been crushed by subsequent pressure but the fact that a very large percentage of the lamellibranchs show the two valves in apposition is a proof that the living animal had been transported from no great distance and that deposition of the sediments in which they are found was of a tranquil nature. The Vemavaram outcrops are separated from those of the Budavada by alluvium, and the nature of the boundary between the two stages is apparently not known, but it is probable that the stratigraphical gap which appears to occur between the Golapillis and the Ragavapurams of the Ellore area does not exist between the Budavadas and the Vemavarams of Ongole ; in fact, there is no evidence against the conclusion that the Vemavaram is a more or less conformable continuation of the Budavada sedimentation.

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[1] *Mem.* XVI, Pt. 1., 71, *Reprint* (1930).

From the Pavulur sandstones no determinable fossils have been obtained though some of the beds contain minute shell fragments scarcely larger than the associated grains of sand, while the uppermost member, and occasionally also the lowest, shows obscure fragments of plants ; since they overlie the Vemavaram shales, they have been correlated with the Tripati sandstones of Ellore. No hiatus has been recorded between the Vemavarams and the Pavulurs. The thickness of the Pavulur stage is small. The beds roll about at low angles but are here and there quite horizontal. The lower sandstones are friable and pale brown in colour ; the middle sandstones are hard and calcareous, slightly shaly, greenish or bluish black weathering to grey or brown ; while the upper sandstones are coarse, friable and reddish brown. The lower sandstones are described as containing flatly lenticular intercalations of a hard dark sandstone similar to that of the overlying beds.

Madras area.—Of the so-called Upper Gondwana beds near Madras there are four principal exposures, one around Sripermatur (Sriperumbudur), a town twenty-five miles W.S.W. of the city of Madras and a well-known locality for fossil plants, a second around Pyanur, a third around Alikur, and a fourth occupying the Sattavedu (Satyavedu ; Sattivedu) hills.[3] The dip of the rocks, though low on an average, is in some places somewhat greater than it is in the Upper Gondwana coast exposures further north, and in one or two cases reaches 40° ; the direction of dip varies. Of the two groups into which the Gondwanas of this area have been divided, the lower, named after Sripermatur, is composed of white fossiliferous shales associated with friable sandstones, grits and micaceous sandy shales. Conglomerates, all of them loose in texture and uncompacted, occur, especially towards the base where they are coarse and occasionally contain boulders of great size. It is not unlikely that the basal conglomeratic and sandy portion of the Sripermatur beds corresponds to the Budavada stage of the Ongole area, but no separate name has ever been suggested for them. A boring near Madras penetrated beds of carbonaceous shale which are concealed at the surface by overlap but which were thought by Foote to represent the Damudas; the depth attained was 660 feet but no coal was encountered.[1]

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[1] A collection made by L. A. N. Iyer in 1927, presumably from both the Budavada and Vemavaram subdivisions, included specimens of *Leda, Lucina, Ostræa, Exogyra, Pecten, Aucella, Area, Tellina, Cyrena, Lima* (casts), a doubtful *Trigonia, Cardium, Pronœlla, Alectryonia, Mytilus, Patella* (several species), *Natica* (casts), *Rhynchonella* (several species), *Terebratula* (several species) and fragments of belemnites and ammonites [*Rec.* LXI, 21 (1928)].

[2] O. Feistmantel. *Rec.* X, 193 (1877). Not from the Sripermatur group, as stated by Feistmantel.

[3] R. B. Foote. *Mem.* X, 64 (1873).

The Sripermatur shales contain both animal and vegetable remains in the form of ill-preserved shells and fragmentary plants which in places are mixed up together; logs and twigs of silicified wood are occasionally found in some of the beds. Most of the shells never seem to have been specifically determined, probably on account of their thinness and consequently poor preservation; they comprise two or three species of ammonites—including the one found in the Ragavapuram shales—which, Waagen noted, resemble Neocomian rather than Jurassic forms, and many lamellibranchs belonging to *Leda, Yoldia, Tellina, Psammobia, Lima, Pecten, Inoceramus* (*I. mytiloides*), and others.[2] The plants are numerous in certain sections and fragmentary, and like those of the Ragavapuram shales, represent a mixed flora of Rajmahal types, Jabalpur types and types peculiar to the shales in question; a list is given in the tabular statement.[3]

The Sripermatur stage is overlain by a set of beds of coarse, compact conglomerate, with intercalated sandstones and grits, which are distinguished as the Sattavedu stage, after some ridges of that name northwest of Madras. The conglomerates are made up of a very coarse shingle, sometimes of quartzite, sometimes predominantly of granitic rocks, often in a ferruginous, calcareous, siliceous or mixed cementing material which in some cases is of great hardness, in others friable. The majority of the sandstones are reddish in colour, and yellow cherty mudstones are recorded in one section. In the Sattavedu type area, the Sripermatur stage is not present, and elsewhere the junction between the two stages is ill seen; they appear to be conformable to each other, and it is doubtful whether there is sufficient justification for the separation of the upper as a distinct subdivision. The plant fossils so far found in the Sattavedu sandstones and mudstones are very fragmentary and largely indeterminable, but a *Dictyozamites* has been recognised. This stage is generally regarded as corresponding to the Tripati sandstone of Ellore and the Pavulur sandstone of Ongole. Upper Cretaceous beds of Ariyalur (Campian-Mæstrichtian) age occur in the Sripermatur area.

Trichinopoly area.—The Upper Gondwanas of the Trichinopoly district occur as narrow outcrops along the western edge of the marine Upper Cretaceous (Albian-Cenomanian) beds, which they separate from the gneissic rocks. The gneiss, where the Gondwanas rest upon it, is decomposed to a considerable depth; this decomposition is not seen in the immediately surrounding country and is rarely found where beds other than the Gondwanas rest upon the gneiss.[4] The inclination of the beds is generally low but the dip in places rises to 15° and 20°. These Gondwanas, which are known as the Utatur Plant Beds, stretching in some five or six isolated patches for a distance of about twelve miles in a N.-S. direction, are unconformably overlain by the Upper Cretaceous marine Utatur series which overlaps them at both ends ; the most important of the outcrops is one near Utatur (Ootatoor). The rocks of the Utatur Plant stage consist chiefly of soft sandy clays and micaceous shales, with sandstones and a coarse conglomerate of rounded gneiss pebbles at the base. The conglomerate has a ferruginous matrix and includes large blocks of much decomposed gneiss, some of them five or six feet across. Some of the sandstones are current-bedded; some are characterised by large calcareous concretions of a flattened spheroidal shape.

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[1] V. Ball & R. R. Simpson. *Mem.* XLI, 104 (1913).

[2] *Pal. Ind.*, Ser. IX, Vol. 1, 236 (1873-76); F. Stoliczka. *Rec.* I, 59 (1868).

[3] O. Feistmantel. *Pal. Ind.*, Ser. II, Vol. I, Pt. 4, p. 3 (1879).

[4] H. F. Blanford. *Mem.* IV, 40 (1862).

In the finer beds, and especially in the soft, grey, micaceous shales, fragmentary and fragile plant impressions, principally of *Ptilophyllum* ("*Palæozamia*"), are not uncommon ; a list of species collected by Foote is given in the tabular statement.[1] The only animal remains recorded are casts of a small bivalve shell and this is reported only from the Maruvattur (Maravatur) exposure. At the same time, a boulder bed assigned to the base of the marine Utatur series in Trichinopoly is identical in every way with boulder beds of the East Coast of Upper Gondwanas; at Kailakkudi (Cullygoody) this Utatur boulder bed is overlain by fine micaceous shales, grey sands and intercalated grit bands, which very much resemble certain members of the plant-bearing Upper Gondwanas but contain marine fossils instead of plant remains. The marine fossils include a belemnite bearing some resemblance to an Utatur species, but are otherwise peculiar to this Kailakkudi deposit and do not appear to have been met with elsewhere in beds of the marine Utatur series.

The outcrops at Utatur are the most southerly which contain Gondwana plant impressions, but some unfossiliferous shales and conglomerates exposed in the Madura district closely resemble the coastal Gondwanas.

Age of the East Coast beds.—From the lists tabulated on page 97, it will be seen that not only are there a certain number of forms common to two or more of the Ragavapuram, Vemavaram, Sripermatur and Utatur Plant stages, but that in each case the flora is characterised by a large proportion of Rajmahal species and a much smaller proportion of forms which are known only from the Jabalpore and Umia stages. Apart from the presence of Jabalpur species and species peculiar to these outliers, their flora is distinguished from the true Rajmahal flora by the absence of broad-leaved Tæniopterideæ, and by the greater abundance of certain forms such as *Tæniopteris* (*Angiopteridium*) *spatulata* and *Dictyozamites indicus*, which, though not unrepresented, form a smaller proportion among the Rajmahal species.[2] The presence of the genus *Tæniopteris* and the smaller proportion of purely Jabalpur species in the Utatur Plant beds might mean that these particular beds are somewhat nearer in age to the Rajmahal than the other three formations but, with this possible exception, the stages under consideration might be taken as being approximately of the same age, were it possible to assume that the plant remains are all indigenous to the beds in which they are found.

A recent examination of the poorly preserved ammonites from the Budavada, Ragavapuram, Vemavaram and Sripermatur stages has led to some interesting conclusions. In the first place, Dr. Spath has detected no essential difference in the fauna of the lowest group—the Budavada—and the faunas of the three slightly younger groups, the Ragavapuram, Vemavaram and Sripermatur, and has treated the aggregate assemblage as one fauna, which, he suggests, is intermediate between the widely distributed *Holcostephanus* fauna on the one hand and the Aptian faunas known in Cutch, Madagascar and Australia on the other. The provisional identifications include two new genera, *Pascœites*, a link between the Holcodiscidae and the Hemihoplitidae, and related to the crioceratids as well as to *Gymnoplites* also probably one of the Holcodiscidae :

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[1] R. B. Foote. *Rec.* XI, 257 (1878) ; O. Feistmantel. *Pal. Ind.*, Ser. II. Vol. I, Pt. 4, p. 9 (1879).

[2] O. Feistmantel *Pal. Ind.*, Ser. II, Vol. I, Pt. 4, p.8 (1879).

Holcodiscus cf. *perezianus* (d'Orb.),[1]
,, cf. *caillaudianus* (d'Orb.),
Hoplites (*Hemihoplites* ?) cf. *borowæ* Uhl.,
,, ,, cf. *beskidensis* Uhl.,
,, ,, *codazzianus* (Karst.),
Lytoceras sp. (cf. *vogdti* Karak.),
Pascœites budavensis Spath,
,, *crassus* Spath,
Gymnoplites simplex Spath,
,, sp. nov.

The affinities of this assemblage are considered to be sufficiently definite to point to an Upper Neocomian (Barremian) age, a conclusion which would make it a whole geological system younger than the Lower Jurassic Rajmahal Plant bed stage. The plant assemblages of the Golapilli and Athgarh stages have always been described as typically Rajmahal, though the former includes one Jabalpur species, and the flora of the Ragavapuram, Vemavaram and Sripermatur stages was for a long time referred to the same stratigraphical level and the beds were spoken of as the Rajmahals of the East Coast.[2] The flora of these East Coast stages, however, has Jabalpur affinities and is obviously intermediate in age between the Rajmahal and the Jabalpur, belonging to some horizon in the Middle Jurassic. This is where Professor B. Sahni placed it, with the title of the Kota flora, equating the beds with the Kota stage, ill-established as it was, of the Godavari valley. A Lower Cretaceous age for the Ragavapuram, Vemavaram and Sripermatur stages is, therefore, entirely unacceptable to palæobotanists on the grounds that their flora is not comparable to Cretaceous floras in other parts of the world. That there has been some error in field-work or a mislabelling of specimens will be rejected by anyone who has read the descriptions of Foote and King or Dr. Spath's remarks.[3] The evidence of the East Coast flora, pointing to a Middle Jurassic age, is claimed to be as irrefutable as the evidence of the ammonites, which cannot be older than Upper Neocomian, and the only acceptable solution of the quandary, as the author has indicated elsewhere, is a presumption that the plant remains are not indigenous but are derived from beds older than the marine sediments with which they have become so closely associated. In the latter case, the so-called East Coast flora may be a mixed assemblage, derived partly from Rajmahal and partly from Jabalpur rocks ; alternatively, it may be a true flora whose source was some Gondwana stage intermediate in age between the Rajmahal and the Jabalpur. It seems possible for blocks of plant-bearing Jurassic rocks to have fallen, in early Cretaceous times, from low cliffs into some protected delta or coastal lake similar to the Chilka, Pulicat and other semi-enclosed tracts of water which still characterise this coast, and to have become intimately mixed with ammonite-bearing marine Cretaceous sediments. That

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[1] Dr. Spath spells the genus "*Olcostepphanus*".

[2] *Vide* attached table (East Coast).

[3] At Maravatur, the plant beds appeared to pass up conformably into sediments belonging to the marine Cretaceous Utatur group. Dr. T. Oldham, on the other hand, concluded that a concealed unconformity separated the plant bearing beds from the Utatur marine sediments ; Mr. Foote agreed with Dr. Oldham but admitted that stratigraphical evidence of a break between the two was wanting (*Rec.* XI, 251 (1878)).

THE PLANT ASSEMBLAGES OF THE EAST COAST BEDS ARE LISTED BELOW :—

	Ragavapuram.	Vemavaram.	Sripermatur.	Utatur Plant beds.	REMARKS.
Pteridospermae ?					
Thinnfeldia subtrigona (Feistm.),	..	+	..	..	
Filicales.—					
R. *Cladophlebis indica* (O. & M.),	..	..	+	+	
R. J. ,, *denticulata* Brongn,	..	+	+	..	"*Alethopteris whitbyensis.*"
Cycadophyta.—					
R. J. *Taeniopteris* (*Angiopteridium*) *spatulata* (Morr.),	+	+	+	+	
R. *Taeniopteris* (*Angiopteridium*) *maclellandi* (O. & M.),	+	+	+	..	
R. J. *Ptilophyllum acutifolium* (Morr.),	+	+	+	..	
R. J. ,, *cutchense* (Morr.),	..	+	+	..	Including "*Otozamites angustatus.*"
R. *Otozamites bengalensis* (Morr.),	+	+	+	..	
,, *bunburyanus* Zign., var. *indica* Sew. & Sahni,	..	+	+	..	
,, *parallelus* (Feistm.),	..	+	..	..	
J. ,, *hislopi* Oldh.,	..	+	..	..	
R. J. *Dictyozamites indicus* (Feistm.),	..	+	+	+	
Pseudoctenis footeana (Feistm.),	..	+	+	..	"*Pterophyllum footeanum.*"
R. *Nilssonia fissa* (Feistm.),	..	+	..	..	"*Anomozamites fissus.*"
Ginkgoites.—					
Ginkgoites crassipes (Feistm.),	+	..	+	..	
Coniferales.—					
Elatocladus plana (Feistm.),	+	+	+	..	
R. J. ,, *conferta* (Morr.),	..	+	+	..	

R. J. *Elatocladus tenerrima* (Feistm.),	..	+	+	..	"*Taxites tenerrima.*"
J. ,, *jabalpurensis* (Feistm.),	..	+	..	..	
,, (? *Torreyites*) Sp.,	..	+	..	..	
Torreyites constricta (Feistm.),	..	..	..	+	"*Cycadites constrictus.*"
R. J. *Brachyphyllum expansum* (Sternb.),	..	+	+	..	"*Echinostrobus expansus*"; close to *B. mamillare.*
R. J. ,, *mamillare* (Brongn.),	..	..	+	..	"*Echinostrobus rajmahalensis.*"
J. ,, *rhombicum* (Feistm.),	..	..	+	..	Close to *B. mamillare.*
,, *feistmanteli* (Halle),	..	+	..	..	Originally assigned to *Pachyphyllum* (*Pagiophyllum*) *peregrinum.*
R. J. *Retinosporites indica* (O. & M.),	..	+	..	..	
J. *Araucarites cutchensis* (Feistm.),	..	+	+	?	
J. ,, *macropteris* (Feistm.),	..	..	+	?	
Cupressinoxylon alternans Sahni,	+	..	..	..	
,, *coromandelinum*,	..	..	+	..	
Mesembrioxylon parthasarathyi Sahni,	..	..	+	..	
Conites sessilis Sahni,	..	..	+	..	Cones.
,, *sripermaturensis* Sahni,	..	..	+	..	,,
,, *verticillatus* Sahni,	..	..	+	..	,,
Dadoxylon (?) Sp.,	..	..	+	..	
Incertae sedis.—	..	..	+	..	
J. *Desmiophyllum indicum* Sahni,	+	..	..	..	

such an event actually happened requires confirmation but has been assumed for the time being. Should further investigation prove that the plants are indigenous to the beds in which they occur, few will hesitate to accept the testimony of the ammonites as opposed to that of the plant fragments, and the only conclusion possible in such an eventuality would seem to be that the numerous plants common to the Rajmahals and East Coast beds are but an example of the slower evolutionary changes during Upper Gondwana times as compared with those which obtained in the Lower Gondwana period. Accepting the suggestion that the plant remains are accidental enclosures in marine beds which form part of the marine Cretaceous succession of the Coromandel coast, it is questionable whether the term Upper Gondwana is rightly applicable to stages such as the Budavada, Ragavapuram, Vemavaram and Sripermatur.

Whether Gondwana or pseudo-Gondwana, the stages under consideration may be reviewed severally as follows. There is no definite reason for assigning any other age but that of Rajmahal to the Athgarh Sandstone of Cuttack. The Golapilli beds may well belong to the same epoch, in which case there must be a marked, though apparently invisible, unconformity between them and the overlying Ragavapuram shales ; if no unconformity exists, the deduction follows that the Golapilli plants are mostly if not entirely derived. The Budavada, Ragavapuram, Vemavaram and Sripermatur stages belong to the Lower Cretaceous and are not older than Upper Neocomian, a conclusion founded on ammonite evidence. The Tripati, Pavulur and Sattavedu stages are of either Barremian or Aptian age. The Utatur Plant beds contain no marine fossils but are overlain by the Utatur marine group. Mr. H. F. Blanford gained the impression that the former were not much older than the latter, and for that reason gave the same name to both as members of one stratigraphical unit.[1] Since the marine Utatur group is for the most part Cenomanian with a possible transgression down into the Albian, the Utatur Plant beds, if not much older, might well be of Upper Neocomian age like the Ragavapuram-Vemavaram-Sripermatur stage, in which case its plants would have to be regarded as derived. The alternative is that the Utatur plants are indigenous and the beds of an age either equivalent to the Rajmahal or intermediate between the Rajmahal Plant beds and the Jabalpurs ; in the latter case, they would correspond to Sahni's Kota stage, the equivalent of some portion of the Rajmahal traps. Further research may be able to decide which of these alternatives is correct. If the Utatur plant remains are indigenous, they might have provided the source of the derived plants found in the Ragavapurams, Vemavarams and Sripermaturs ; on the other hand, the flora of the latter stages might be a mixed assemblage derived partly from Rajmahal and partly from Jabalpur rocks.

According to Dr. Raj Nath, there are in the Umia series of Cutch higher sandstones than the Valanginian or Infra-Valanginian *Trigonia* bed which was always thought to be near the top of the series. These higher beds, occupying a position between the *Trigonia* bed and the undoubtedly Aptian outlier of Ukra Hill, are the only ones which, in the light of Dr. Spath's determinations, could be correlated with the Budavada-Ragavapuram sequence or its equivalents.

GONDWANAS OF CEYLON.

At Tabbowa in northwest Ceylon, Mr. E. J. Wayland has collected : *Cladophlebis reversa* (Feistm.) (Feistmantel's " *Pecopteris reversa* ")—a species found on the Madras coast and possibly identical with *Todites williamsoni* (Brongn.)—,*C.*

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[1] *Mem.* IV, 14-15 (1862).

denticulata Brongn., *Tæniopteris spatulata* McClell., *Araucarites cutchensis* Feistm., *Brachyphyllum mamillare* Brongn., *Elatocladus plana* (Feistm.), and *Desmiophyllum* sp., all identified by Seward and Holttum.[1] Five—possibly six—out of the seven forms are identical with leaves from the Madras coast outliers. The two authors ascribe a Jurassic age to the Ceylon beds, and date them probably as the equivalents of the Lower Oolite. Mr. K. Jacob has since identified *Coniopteris hymenophylloides* Brongn. and *Anomozamites* (?*Nilssonia*) sp. from the same locality.[2] Mr. R. V. Sitholey has, furthermore, described two new species, *Cladophlebis zeylanica* and *Sphenopteris wadiai*, and has recognised the genera *Ptilophyllum* and *Otozamites*.

GONDWANAS OF WESTERN RAJPUTANA.

Bap Boulder Bed.—Along the eastern fringe of Jaisalmer State in western Rajputana, extending for some thirty-five miles in a N.E.-S.W. direction, a little to the west of the town of Bap, is an irregular exposure of boulder beds which in all probability are the equivalents of the Talchir. They consist of a matrix of fine-grained marl in which are scattered numerous fragments, many of them unrounded, of felsite, red syenite, porphyry, limestone, gneiss and granite, of all sizes from a few inches to, in one case, over ten feet across, numbers of them showing glacial smoothing and striation. Amongst the fragments can be recognised the Malani lavas and limestone from the Vindhyans; the latter must have been indurated and metamorphosed at the time of the deposition of the boulder beds, and its presence affords some assistance in dating the boulder beds.[3] Near Bap, some beds of impure limestone are associated with the boulder beds. There is some reason for believing the Bap boulder beds to be much younger than the somewhat similar conglomeratic and agglomeratic beds forty miles to the S.S.W. around Pokaran, which are thought to be basal Vindhyan, and have been described under that heading.[4] To which of the two belongs the conglomeratic bed at Udhania (Odhania), some fourteen miles west of Pokharan, is not certain, but since it is described as in places passing up into the Lathi sandstones which are almost certainly of Gondwana age, it probably represents the Talchirs; this conglomerate consists of various pebbles, chiefly of felsite, in a matrix of red grit.[5]

Lathi series.—On the northwestern side of the boulder beds at Bap is an ill-exposed thick series of dark red shaly sandstones and clays impregnated with salt, which has been designated the Lathi series. This series is also seen in large isolated exposures cropping out from the sandy alluvium between Pokaran and Jaisalmer. These beds with a slight dip to the W.N.W., occur stratigraphically between the boulder beds and the marine Jurassic limestones of Jaisalmer, and are not less than 2,000 feet thick and may possibly be three times that figure. At their lower limit they appear in places to pass down gradually into the boulder beds.

Wherever the rock immediately overlying the boulder beds is seen, it is a hard, dark-coloured, ferruginous sandstone with or without pebbles. Hard ferruginous bands and patches also abound in the uppermost sandstones of the series. Many of the Lathi sandstones are comparatively soft and often reddish in colour or variegated. In some there are indistinct vegetable fragments, sometimes occurring in abundance, and large blocks of silicified wood.[1] A few limestone beds are inter-stratified with the sandstones. Some of the lower sandstones are shaly.

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[1] *Q.J.G.S.*, Vol. LXXVIII, 271-276 (1922).

[2] *Journ. Ind. Bot. Soc.* XVIII, 205 (1940).

[3] R. D. Oldham. *Rec.* XIX, 123 (1886); *Ibid.*, XXI, 31 (1888).

[4] A. M. Heron. *Rec.* LXV, 467 (1931).

[5] W. T. Blanford. *Rec.* X, 14 (1877).

Some of the Lathi sandstones have been compared with the Mahadevas or Kamthis, the dark ferruginous bands corresponding to the iron bands in each of these Gondwana formations but, if the basal beds pass down into the Talchirs, the Lathi rocks must include beds equivalent in age to the Barakars—perhaps to much of the Damuda series— a suggestion borne out by the numerous plant remains and the ironstones.

Barmer Sandstone.—To the north and east of the town of Barmer, in the State of Jaisalmer, several small patches of a plant-bearing sandstone are seen cropping out from the alluvium, and probably represent the highest horizons of the Upper Gondwana. The rock is light grey in colour, breaking with a conchoidal fracture where locally indurated; sometimes it is soft, and veined or blotched with purple or red. At the base is a thick band of conglomerate, the well-rolled pebbles of which are all derived from the underlying Malani lavas.[2]

It was at one time thought that the Barmer sandstones might be the equivalents of the Lathi beds of the Bap area. The fact that they have yielded some dicotyledonous wood and net-veined leaves makes it probable that they are not older than Lower Cretaceous (Aptian); this supposition is confirmed by the stratigraphical position of a fine unctuous fullers' earth known as *Multani mitti* which, though not definitely seen in contact with the Barmer sandstones, is believed to overlie them, and which, in the northeast of Jaisalmer and in Bikaner, is associated with nummulitic limestones of early Tertiary age. Besides the vegetable remains, the fossils in the Barmer beds include a cast of a *Unio* and the fragment of what may be a *Cardium*.

On the eastern side of the Barmer desert, near the Luni river, patches of the sandstones are seen resting directly upon an uneven surface of the Malani lavas. The upper limit of the beds is concealed by alluvium. At Barmer, the sandstones are extensively quarried for the manufacture of mill-stones and for building purpose.

The Gondwanas of western Rajputana must have been laid down in a valley on the northwestern flank of the Aravalli chain.

GONDWANA EQUIVALENTS IN AFGHANISTAN.

Saighan series.—North of the Hindu Kush and the continuing range westward which unite it to the Safed Koh, in the Saighan and Kamard areas of Afghan-Turkistan, the most extensively exposed geological formation, with the exception of the Cretaceous, is a series of shales, sandstones, grits and conglomerates, designated by Hayden the Saighan series. A small outcrop of these beds is also seen on the southern or Bamian side of the Koh-i-Ghandak, and the formation has been recognised in eastern Persia.[3]

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[1] Thought by Blanford to be dicotyledonous.

[2] K. T. H. D. La Touche. *Mem.* XXXV, 33 (1902).

[3] G. H. Tipper. *Rec.* LIII, 58 (1921).

So far as its age and lithological facies are concerned, this series corresponds to some part of the Upper Gondwana succession, for the shales are often highly carbonaceous, containing well-preserved plant remains and seams of coal; in the Darra-i-Suf area, there are considerable reserves of coal, according to Dr. West. The arenaceous beds are usually brown, while the argillaceous types range from almost white to black according to the proportion of carbonaceous material present.[1] While the Cretaceous limestone caps the hills, the plant-bearing series occurs in the valleys and has been noted in those of Saighan, Hajar, Aokhorak (Khorak) and Chehil (Chail), and in Darra-i-Suf. Seventy miles or so to the north of the Chehil outcrop, a larger inlier is exposed in the Cretaceous south of Mazari-sharif, and two other inliers have been mapped between this and Bala Murghab. In this region, most of the streams which have cut down into the anticlines along the northern slope of the Kara Koh, have laid bare, beneath the Cretaceous, strata ranging from Middle Trias to Jurassic.[2] North and northwest of Herat, extensive exposures of this series have been mapped, and with them must be included a small outcrop west of Ghurian.

In the Herat area, the Saighan series rests upon Carboniferous limestone, but further east, near the junction of the Kahmard and Saighan rivers, it lies upon the Doab, a series which there is some reason for correlating with the Panjal Volcanics of Kashmir. While the dip here in the Doab rocks is frequently very variable, that in the overlying Saighan beds is very uniform, and Dr. West concludes that there is a pronounced unconformity between the two formations; this conclusion is confirmed by signs of an old land surface, in the shape of red and white beds, along the uppermost boundary of the Doab series—a land surface which obliquely truncates members of the Doab succession. In a northeast direction from Ishpushta, the lower members of the Saighan series gradually die out, so that the rocks forming the middle portion of the Saighan come to rest upon the Doab series. The Saighan series is overlain in apparently conformable succession by the Red Grit series (Lower Cretaceous) and the Upper Cretaceous limestone; in the Darra-i-Suf area, however, there is an unconformity at the base of the Red Grits, if they are present, or at the base of the Cretaceous limestone, if they are not.

What appears to be a complete and continuous section of the Saighan series is to be seen at Ishpushta on the left bank of the Surkh-ab (the river formed by the junction of the Kamard and Saighan rivers, and not to be confused with the Surkh-ab between Jalalabad and Jagdallak). It is here that the Saighan beds are seen lying with little or no angular discordance upon the old land surface of the Doab series.

This plant-bearing series, in the Chehil section is underlain by a calcareous sandstone from which specimens of *Halobia* related to Upper Triassic or perhaps younger species have been collected by Griesbach. This alone would suggest a Jurassic age for the Saighan beds, a correlation which is confirmed by the flora obtained from the latter, chiefly from Chehil and Shisha Walang, and determined as follows :—

Equisetales—

Equisetites ferganensis Sew.,	Hardly distinguishable from the European, *E. columnaris* Brongn. and most typical of the Middle Jurassic.

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[1] H. H. Hayden. *Mem.* XXXIX, 30 (1911).

[2] C. L. Griesbach. *Rec.* XIX, 243 (1886).

Epuisetales—*contd.*
  Epuisetities spp. (three),
  „ sp., cf. *Neocalamites carreri* (Zeill.), More Rhætic or Liassic than Middle or Upper Jurassic in type.
  Schizoneura ? sp.,

Filicales—
  Klukia exilis (Phill.),
  Coniopteris hymenophylloides (Brongn.),
  Sphenopteris ? sp.,
  Haydenia thyrsopteroides Sew.,
  Dictyophyllum sp.,
  Cladophlebis denticulata (Brongn.),
  „ *haiburnensis* (L. & H.),
  Sagenopteris phillipsi (Brongn.).,

Cycadophyta—
  Tæniopteris cf. *vittata* (Brongn.),
  Williamsonia haydeni Sew.,
  Nilssonia compta (Phill.),
  „ *mediana* (Leck.),
  „ *saighanensis* Sew.,
  „ *orientalis* (Heer),
  Pseudocycas cf. *dicksoni* (Heer),
  Ctenis cf. *falcata* (L. & H.),

Ginkgoales—
  Ginkgo digitata (Brongn.),
  Stenorhachis lepida (Heer),
  Phœnicopsis potoniei Krasser.,

Coniferales—
  Pityophyllum cf. *staratschini* (Heer),
  Cupressinoxylon orientale Sew.,
  Pagiophyllum setosum (Phill.),
  Taxites sp.,

Incertæ sedis—
  Podozamites lanceolatus (L. & H.),
  „ „ „ var. *latifolius* (Heer),
  „ „ „ var. *angustifolius* Sew.,
  „ *saighanensis* Sew.,
  „ *griesbachi* Sew.,
  „ *kidstoni* Eth.,

Sir Albert Seward's conclusion is that the assemblage as a whole indicates the fragmentary remains of a Middle Jurassic flora, agreeing very closely in general facies with that from the Inferior Oolite series of England.[1] Other interesting features of this flora are its similarity to that from Ferghana, Sur-Darja and other parts of Russian Turkistan, and the important points of difference it shows when compared with the Upper Gondwana floras found in India. Like the Jurassic flora of other parts of the world, those of India possess several cosmopolitan species, but genera such as *Ginkgo, Sagenopteris, Dictyophyllum, Laccopteris, Ctenis, Phœnicopsis* and *Podozamites*, all of which have at one time or another been found in Afghanistan, are either absent, rare or unsatisfactorily represented. The Saighan flora, therefore, belongs to the Angara rather than to the Gondwana province, and we have, in these northern parts of Afghanistan, indications of the presence of the *northern* shores of the Tethys Sea.[1]

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[1] *Pal. Ind.*, New Ser., Vol. IV, Mem. 4, 44 (1912).

Recently Mr. R. V. Sitholey has described a few plant remains collected by Dr. Fox from Chehil and the country to the west and southwest of that lake-bordered small village.[2] As the impressions are of Jurassic age, they come presumably from the Saighan series; they include a few forms additional to those recorded above, *viz.*, Alga-like impressions, *Metonia*-like fronds, a doubtful *Laccopteris*, *Conites* sp., *Mesembrioxylon* sp., and a new *Strobilites*, *S. sahnii* Sith.

Further collections recently made by Dr. W. D. West from the Saighan series of Ishpushta, and described by Dr. K. Jacob and Mr. B. N. Shukla (*Pal. Ind.*, N. S., XXXIII, Mem. 2, 1955) include the following hitherto unrecorded fossils :

Equisetales—
  Neocalamites ishpushtensis sp. nov.,
  Annulariopsis simpsoni (Phill.),
Filicales—
  Todites sp.,
  Klukia Westi sp. nov.,
  Coniopteris quinqueloba (Phill.),
    ,, *arguta* (L. & H.),
  Eboracia lobifolia (Phill.),
    ,, *ahmadi* sp. nov.,
    ,, *densifolia* sp. nov.,
Clathropteris sp.,
Cycadophyta—
  Nilssonia polymorpha var. *major* nov.,
    ,, *curvifolia* sp. nov.,
    ,, *schaumbergensis* (Dunk.),
    ,, *macrophylla* sp. nov.,
    ,, cf. *N. orientalis* (Heer),
    ,, cf. *N. saighanensis* Seward,
  Ctenis afghanensis sp. nov.,
    ,, *constrictus* sp. nov.,
    ,, *approximatus* sp. nov.,
  Pseudocycas saighanensis sp. nov.,
  Pterophyllum ishpushtanum sp. nov.,
    ,, barfakense sp. nov.,
? *Otozamites* sp.,
? *Ptilophyllum* sp.,
Caytoniales—
  Sagenopteris phillipsi var. *afghanensis* nov.,
Ginkgoales—
  Ginkgoites digitatus var. *huttoni* Sternd.,
Coniferales—
  Pityophyllum cf. *P. longifolium* (Nath.),
  Pagiophyllum curvifolium (Dunk.),

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[1] The light grey, much disturbed and shattered limestone of the high hills known as Koh-i-Sultan and Ahmed Kabir, north of the Surkh-ab and west of Jalalabad, well exposed in the Tang-i-Rajan, and classed by Griesbach with the limestone masses forming the Shutargardan and adjoining country south of the Surkh-ab as most probably Rhætic, has not been included as such on Hayden's map. (*Mem.* XXXIX, 20 (1911)).

[2] *Pal. Ind.*, New Ser., Vol. XXIX, Mem. 1 (1940).

Coniferales—*contd.*
Elatocladus cf. *E. plana* (Feist.),
Brachyphyllum cf. *B. mamillare* (Brongn.),
Stachyotaxus elegans Nath.,
,, *distans* sp. nov.,
Dammarites asiaticus sp. nov.

The study of the large collection of plants apparently indicates a somewhat sub-tropical to temperate, comparatively dry climate for most of the region during the time when the vegetation flourished. The presence of marked annual rings in the wood of *Mesembrioxylon* sp. (described in the above memoir) also seems to suggest a climate with marked seasonal variations.

The southern limits of the Jurassic Angara floral belt, extended south-east from Kamenka in the west through Caucasus to Turkistan and Saighan in Northern Afghanistan and then took a sharp northerly bend to Tadzik and probably stretched ESE to Kunlun and further east and north-eastwards to Amurland and the Pacific Coast. The barrier between the northern Angaraland and the southern Gondwanaland was very effective even in the Jurassic period, although migration was comparatively easier during the Permo-Triassic times as suggested by the presence of a few elements of the southern Glossopteris flora in the Ural and Kusnez regions in U.S.S.R.

The plant assemblage taken as a whole is definitely suggestive of a Jurassic age. The closest resemblance of the flora is with those of the Middle Jurassic age from Kamenka, the Caucasus, Eastern Tien-Shan and Amurland, all of which contain several forms common to those regions. Although there are a few forms in the above collections ranging into the Rhaetic and fewer still, extending to the cretaceous, on the whole, the Saighan flora may be referred to the Middle Jurassic.

GONDWANA EQUIVALENTS IN BURMA.

Beds of the same age (Jurassic, perhaps Rhætic) as some portion of the Upper Gondwana occur in Burma but, like the Afghan beds just described, have every appearance of belonging to the northern Angara continent and not to Gondwanaland. They are known as the Loi-an Coal Measures and are described in Chapter XXV.

CHAPTER XXIII.

INDIVIDUAL GONDWANA EXPOSURES.

Topographical grouping. I. **Rajmahal Hills.** II. **Birbhum. Deogarh and Karharbari region:** Birbhum; Sahajori; Jainti; Odd outcrops; Giridih. III. **Damodar valley region;** Raniganj; Jharia; Bokaro: Ramgarh; Karanpura—South Karanpura-North Karanpura; Chope; Itkuri; Kunda, Amjhar and Kisgo; Sherghati; Daltonganj; Sathbarwa; Aurunga; Hutar; Tatapani-Ramkola. IV. **Mahanadi and Brahmani valleys:** Athgarh; Talcher; Hingir; Kankani; Korba-Dharmjaygarh. V. **The great central tract of Sarguja and adjoining country:** Bisrampur; Lakhanpur; Bansar; Panchbhaini; Damhamunda; Sendurgar; Main Pat; Unimportant outliers; Jhilmili; Kurasia; Koreagarh; Sohagpur coalfield; Johilla; Umaria; Korar; Hasdo-Rehar tract; Singrauli coalfield. VI. **Satpura region.** VII. **Narbada west of Hoshangabad.** VIII. **Upper Tapti region.** IX. **Godavari region:** Inliers near Ellichpur; Inliers near Narkher and Kalmeshwar in Nagpur; Kamthi area; Bandar coalfield: Outliers near Khair and Arjuna; Wardha valley, or Chanda-Yeotmal-Adilabad area; Central portion of the Godavari; Outliers northeast and east of Pakhal Tank; Singareni; Southeast extension. X. **Coastal outcrops in the neighbourhood of Madras,** north and south of the Palar river. XI. **Utatur Plant beds of Trichinopoly.** Significance of the East-Coast Gondwana occurrences. XII. **Lower Narbada valley.** XIII. **Cutch and Kathiawar.** XIV. **Idar and Rajputana.** XV. **Garo Hills of Assam.** XVI. **Extrapeninsular occurrences:** Salt Range, Himalaya and Hazara; Afghanistan and Burma.

Topographical grouping.—A brief description of the particular groups formed by the various Gondwana basins will help to complete the story of a formation which has given such a geological individuality to India. For this purpose, the following classificatory scheme will be employed, always bearing in mind that the Talchirs and Barakars are markedly uniform in their character over very wide areas, and that it is only in the epochs which followed that divergent features make their appearance and render correlation uncertain. To what extent regions I and II are integral portions of region III, in spite of the great length and the transverse position of region I, it is at present difficult to say; provisionally the three regions are described as such, as they were in the first edition of this work but it is quite possible that the outcrops of II were at one time co-extensive with those of the Damodar line and that No. I is a terminal expansion of this line of outcrops.

I. Rajmahal region.
II. Birbhum, Deogarh and Karharbari region.
III. Damodar valley region.
IV. Mahanadi and Brahmani valleys.
V. The central tract of Sarguja and adjoining country.
VI. Satpura region.
VII. Narbada, west of Hoshangabad.
VIII. Upper Tapti region.

IX. Wardha-Godavari valley, and adjoining portions of the Coromandol coast.
X. Coastal outcrops in the neighbourhood of Madras, north and south of tho Palar river.
XI. The Utatur plant beds of Trichinopoly.
XII. Lower Narbada valley.
XIII. Cutch and Kathiawar.
XIV. Idar and Rajputana.
XV. Garo Hills of Assam.
XVI. Extra-peninsular occurrences.

I.—RAJMAHAL HILLS.

The Rajmahal hills, the western portal of the Ganges and Brahmaputra, extend from the former river below Colgong southwards to the neighbourhood of Suri in Birbhum. They separate the undulating area of Archæan rocks on the west from the Gangetic alluvium on the east. The hills are flat-topped, but the plateaux which cap them, although horizontal in the north, exhibit a gentle easterly tilt in the south corresponding to the prevalent easterly dip of their component rocks.

The Gondwanas of this tract comprise the following subdivisions :

Rajmahal series (chiefly volcanic)	1,500 feet.
Dubrajpur stage	450 ,,
Barakar stage	500 ,,
Talchir stage	?

In the north, the Gondwana sediments rest upon the Archæan metamorphics ; to the south, their western boundary is a line of fault, while the hard basaltic lavas of the uppermost subdivision form scarps facing the west and dip away gradually eastwards until the whole exposure disappears beneath the alluvium of the Ganges valley. By far the greater portion of the area is composed of the Rajmahal traps, whilst a large tract on the hill-tops is covered with a thick accumulation of laterite.

The Talchir stage is very poorly represented in the Rajmahal area and confined to three small outcrops which have escaped denudation along or very close to the western edge of the Gondwana tract. This stage, which shows excessive and irregular overlap by the Barakars, consists of the usual greenish silts and sandstones and in one or two localities of the boulder bed.

The principal exposures of Damuda rocks, from north to south, are : (i) the Hura coalfield on the edge of the Gangetic alluvium[1] ; (ii) the Chuperbhita coalfield, probably continuous with that of Hura ; (iii) the Pachwara coalfield, the long-flaming, non-caking coal of which is still used in a small way for brick-burning ; (iv) a strip along the western flank of the hills extending for about eight miles southwards from Mahuagarhi Hill, with inliers to the east ; (v) the Brahmani coalfield, bounded on the west by the N.-S. fault.

The coal seams of the Rajmahal region are all shaly and poor in quality, though some of them are of considerable thickness and capable of furnishing a large quantity of inferior coal. In the Hura tract, the friable felspathic grits, with decomposed felspar, together with some soft white shales containing a few seams of inferior coal, may possibly belong to the Raniganj stage ; otherwise the Damudas of the Rajmahal hills appear to show the usual characters of the Barakars.

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[1] The old village of Hura, now known as Lilatari, stands actually on the gneiss.

The Dubrajpur beds, in marked contrast to the Damudas, consist of coarse grits and conglomerates, often ferruginous, and are confined to a narrow strip of the country along the western edge of the hill tract, disappearing eastwards beneath the traps. Even from north to south the occurrence of the Dubrajpurs is capricious, and there is clear evidence that considerable denudation of these beds took place before the commencement of the volcanic epoch. The Dubrajpurs follow the Damudas with a marked unconformity and are to the Rajmahal volcanic beds what the Infra-trappean are to the Deccan Trap (*q.v.*).

The principal exposures of the Rajmahal plant beds are in the northern portion of the hills. The traps and sediments of this series have already been described in detail, and attention has been drawn to the possible presence of a volcanic vent at Simra, now represented by a group of small hills of trachyte.

II.—BIRBHUM, DEOGARH AND KARHARBARI REGION.

The basins of this heading, composed of Lower Gondwana sediments and all of small size, are links between the Rajmahal outcrops and those of the Damodar valley. Their existence would seem to indicate a former extension of Lower Gondwana deposits over a great part of western Birbhum and northern Hazaribagh.

Birbhum.—The Tangsuli outcrop of Barakar rocks lies about six miles northwest of Suri, the principal town in Birbhum. No Talchir rocks have been recognised in this basin-shaped syncline. Two small exposures, one with a faulted southern boundary, the other synclinal in structure, occur further to the west in the Sidh stream. Further west still in Birbhum is the Kandit Karayah tract, mostly of Talchir beds but partly of Damudas, all dipping southwest and cut off in this direction by a fault.

Sahajori.—Across the Birbhum boundary in Deogarh, part of the Santhal Parganas, is the much larger Sahajori field, in which both Talchirs and Barakars are exposed, the former in a much greater thickness than the latter. The boundaries of the area are for the most part depositional, but a fault traverses the tract from northwest to southeast and there are other smaller dislocations. At the southwestern margin, the Barakars overlap the Talchirs and rest upon the gneiss.

Jainti.—The largest Gondwana area in Deogarh is that of Jainti (Karaun) to the west of the Adjai river, stretching as a narrow band for the most part nearly E.-W. ; from the eastern end is given off a southern extension. The E.-W. portion dips northwards, its northern boundary being to a large extent a fault which is parallel to the great fault boundaries of the Damodar valley basins, though its throw is in the reverse direction ; along its southern boundary this E.-W. portion of the belt rests upon the gneiss. Nearly four-fifths of the whole exposure consist of Talchir rocks, the rest being Barakars. Amongst the boulders in the Talchir boulder bed are some of great size, consisting of granite and gneiss as well as of quartzites very similar to those seen in the Kharagpur hills of Monghyr sixty miles away. Concretions of impure argillaceous limestone in parts of the Talchirs have yielded a few fossil plants. In the Barakars are some thin seams of coal, some of which is of good quality ; many of the seams, however, have been spoiled by intrusions of mica peridotite. The western end of the field is traversed by a large dolerite dyke.

Odd outcrops.—Southwest of Deogarh town is another small Gondwana basin consisting of Talchir rocks. A small area of Barakar rocks is seen across the Baghdaru stream, a mile south of Kharjori ; no seams of coal are present and the rocks are traversed by at least two dolerite dykes. Small Talchir outcrops have been noted in other parts of the Santhal Parganas, including the following : one near Makranda in the Sidhisari valley ; four down the Adjai valley from Alaura ; another at Alakbera, below the junction of the Jainti and Adjai rivers ; another at Ghusi ; and two smaller ones near Barchandi. There is a large outlier of the same rocks in the valleys of the Damgari and Pichri streams, above and below Ladudai, and at least three others up the Barakar river, on and near the confluence of the Irga and Barakar rivers at Bardaha. Further to the west, in northeastern Hazaribagh, are four small tracts of Talchirs.

Giridih.—Some twenty-three miles due north of the Jharia coalfield is the small but important Giridih or Karharbari coalfield ; it is 11 square miles in area, 8 square miles consisting of Karharbari rocks, the rest of Talchirs together with some inliers of gneiss. Some conglomerates of small quartz pebbles in the southeast of the field are doubtfully referred to higher Barakar horizons. The northern and southern boundaries of the field are faulted in parts and nearly straight, directed in each case approximately WNW-ESE. The throw of the faults is, however, small, and Gondwana sediments are found in places south of the southern fault. The field is traversed from WNW to ESE by other faults, the most important of which appears to form the southern boundary of the large gneissic inlier on which stands the village of Karharbari ; eastwards this fault splits into several minor branches. Except along the faults, the beds dip generally from all boundaries towards the middle of the field. Away from the northern and southern boundary faults, the rocks, as a rule, are very little disturbed.

The Talchirs, which are about 600 feet thick, are overlapped by the Karharbaris at the eastern end of the basin ; they everywhere surround the gneissic inlier referred to except along its southern boundary where the Karharbaris have been brought up against the gneiss by the median fault mentioned above. The Karharbari beds, which have already been described in detail, are here some 500 feet in thickness and include seams of first-class coking coal equal if not superior in quality to the best coals of Raniganj or Jharia. The main seam, from 12 to 16 feet thick, lies close to the base of the stage. Dykes of igneous rock, varying in direction, are numerous, and some of them have seriously injured the coal seams.

Minor outcrops of Talchirs in Hazaribagh.—About nine additional occurrences of Talchir beds have been recorded further west in the Hazaribagh district.

III.—DAMODAR VALLEY REGION.

The important coalfields of the Damodar valley form a chain of Gondwana basins running east and west, and separated from each other by very short distances. The valley lies south of the tract in Birbhum and northern Hazaribagh, the two regions approaching each other to the eastward but being separated to the west by the Hazaribagh plateau, on which are found no Gondwana rocks with the exception of one small outlier thereof. The small basins near Hazaribagh and Daltonganj are classed with the present group ; they form links with the more extensive areas of the Son valley. The basins under consideration, therefore, include the following :

A. Damodar valley—
  - (i) Raniganj ;
  - (ii) Jharia ;
  - (iii) Bokaro ;
  - (iv) Ramgarh ;
  - (v) Karanpura
    - North ;
    - South.

B. Northwest Hazaribagh, Gaya and Palamau—
  - (vi) Chope ;
  - (vii) Itkuri ;
  - (viii) Sherghati ;
  - (ix) Daltonganj ;
  - (x) Sathbarwa and other basins in Palamau.

C. Westward continuation of the Damodar valley line—
  - (xi) Aurunga ;
  - (xii) Hutar ;
  - (xiii) Tatapani-Ramkola.

Raniganj.—The Raniganj, formerly known as the Burdwan coalfields from the Bengal district in which a portion of it lies, is the most easterly of the chain of coalfields which follow approximately the Damodar valley. Traversed from west to east by the river, this field, some 18 or 19 miles across from north to south, covers a visible area of about 600 square miles, but there is no doubt that the rocks of the basin extend farther to the east under the laterite and alluvium of the Ganges valley. The eastern limits of the field are thus hidden and not known. On the northwest and south, it is bounded by Archæan rocks.

The beds exposed include :

		Maximum thickness
4. Supra-Panchet (? Dubrajpur stage)		1,200 feet
3. Panchet		2,000 ,,
2. Damuda series	c. Raniganj	3,400 ,,
	b. Ironstone Shales	1,350 ,,
	a. Barakar	2,100 ,,
1. Talchir		950 ,,
		11,000 ,,

The so-called Durgapur beds, which appear to be younger than the Panchet, are either the equivalents of the Supra-Panchet group or are of Miocene or even younger age. The structure of the basin is comparatively simple, the dip over the greater portion of the area being towards the south. In the north it is usually about 5° and rarely exceeds 10°, but towards the southern edge of the basin there are extensive rolls in the strata and frequently high dips ; finally, along the southern edge itself, the Gondwana strata are everywhere turned up at high angles abruptly against the Archæan in a well defined fault. Independent of the southern boundary there are several large faults within the field itself. Along the northern boundary several nearly parallel faults, with a general NW-SE direction, throw the rocks in succession, each having a downthrow to the northeast. One patch of Barakars thrown by the faulting farthest to the northeast is quite unconnected with the main outcrop; another fault runs for some miles almost down the bed of the Adjai river. The lowest Gondwana stage—the Talchir—is, therefore, exposed along the northern boundary and, speaking generally, is followed southwards by successively newer horizons, the Raniganj and Panchet beds cropping out over wide areas of the southern half of the basin.

Both of the two distinctive types of igneous intrusion are seen in this field, the doleritic or basaltic dykes of regular habit, and the ultra-basic dykes and sills of mica-peridotite and lamprophyre which exhibit considerable variation in their mode of occurrence. The former traverse Gondwanas and Archæans alike and are unaffected by the faulting of the coalfield; their direction is usually NW-SE or NNW-SSE. The ultra-basics, on the other hand, are confined to the Gondwana beds and appear to be intimately associated with certain of the faults of the area. It is these intrusions, varying from moderately regular dykes to anastomosing sills, which have availed themselves of the easy access afforded by the coal seams and have wrought such havoc among the latter in certain areas. Though widespread in the Raniganj measures, these intrusions are more abundant in the Barakar stage, and this is one of the reasons why the Barakar coal seams are for the most part inferior in quality to those of the higher-lying Raniganj stage. These ultra-basics form a number of narrow dykes in the overlying Panchet strata of the southern portion of the field.

According to Mr. Gee, the evidence of the Raniganj area indicates a sequence of events beginning with earth movements resulting in at least the major displacements of the Gondwana strata, followed very closely by the intrusion of mica-peridotite and lamprophyre, and ultimately by the dolerite intrusions which were definitely subsequent to the faulting. The Talchirs are well developed in the northwest of the basin and here appear to pass up into the overlying Barakars; to the east and also to the southwest they die out.

Some of the Barakar coal exhibits a peculiar spheroidal structure, and round balls thereof of various sizes up to more than a foot in diameter break away from the mass when the coal is mined. The proportion of coal in the lower Damuda beds is at times large. In one section, totalling 833 feet of rocks, an aggregate of no less than 175 feet consists of coal. It is, however, exceptional to find any seam continuing unchanged throughout a large area, and so irregular are the Barakar seams in thickness that beds several feet thick are sometimes seen to thin out and disappear entirely within a few yards. This thinning-out is especially rife when the roof of the seam consists of coarse sandstone, and in such cases it is evident that, through some change in the circumstances of deposition, the coal has been swept away and replaced by an accumulation of sand. There is also a notable tendency for the seams to vary in quality within short distances.

The Ironstone Shales, which overlie the Barakars, occupy a well marked ridge of raised ground traversing the coalfield from east to west, their elevation being due to their superior power of resisting disintegration; they thin out and are overlapped by the Raniganj group in the southwest corner of the field. The proportion which the ironstone bands bear to the shales varies. In one measured section of 150 feet, 26 bands of iron ore were counted, the aggregate thickness of which was about 8½ feet, or 1 in 17½, the rest being shale; elsewhere, in a sunk pit, the proportion was 1 in 9, but in this case three-quarters of the iron ore was "black band" which contains less iron. The shales appear, in some cases at all events, to be quite impermeable to water—an important advantage in mining. The clay ironstone of the Ironstone Shales was for a number of years mixed with a high-grade iron ore from elsewhere and used in the blast furnaces of Kulti.

The coals of the Raniganj stage, in many cases superior in quality to those of the Barakar, are, furthermore, constant in thickness and quality over larger areas and are known only in a few cases to have been seriously injured by volcanic intrusions; the basalt dykes which traverse these rocks as a rule affect only the coal in immediate contact and do not ramify through the seams. The proportion of coal to the total thickness of strata is very much less in the case of the Raniganj stage than it is in the case of the Barakar.

In the southwest part of the field, a bed of magnesian limestone has been found in the lower portion of the Raniganj stage, and has been quarried for a supply of flux to iron-works; it has been traced over a considerable area to the northeast, where, however, it becomes more sandy and impure, splitting apparently into smaller bands intercalated with sandstone. Calcareous sandstones are common in the Raniganj stage. A band of ironstone in the upper portion of the Raniganj stage affords assistance in tracing the relations of this stage to the overlying Panchets, for it can be followed by the fragments found on the surface over a large area.

The Ramnagar, Begunia, Sanctoria and Deshergarh seams, as well as certain sections of the Laikdih seam, are composed of first-class coal which, either alone or when carefully mixed with a strongly caking coal, will yield a hard coke suitable for metallurgical purposes. Of the 270 million tons of coal extracted from this field up to 1934, Gee estimates that some 30 per cent. (81 million tons) consisted of such coal, 40 per cent. (108 million tons) of superior-quality non-coking coal, and 30 per cent. (81 million tons) of inferior coal. The total reserves of coal in Raniganj down to a depth of 2,000 feet in 1934 were calculated to be 8,679,926,000 tons. The present annual output is something like 6½ million tons, *i.e.*, about 30 per cent. of India's total.

The Panchets occupy a basin in the middle of the field and extend to the southern margin; they are also found in two smaller areas along the southern edge, one of them incompletely surrounding Panchet Hill, the largest and highest hill in the coalfield. The change to the Panchets is usually marked by the occurrence of red clay on the surface of the ground. The felspar, which forms a considerable proportion of the sandstones of the Panchet group, remains undecomposed instead of being converted into kaolin as it has been in the case of the Damuda sandstones; in consequence, the sandstones of the younger group are more fusible, and bands of hard, semi-fused rocks, on each side of the basaltic dykes traversing the beds, can be seen standing out like walls in places near the Damodar river. The Panchets are extremely micaceous throughout. The reptilian bed of this formation is best exposed in the bed of the Damodar near the village of Deoli.

Resting, probably with an unconformity, on the Panchet strata are some coarse, pebbly, ferruginous sandstones and subordinate dark red clays, forming the upper portions of Panchet, Gorangi and Biharinath hills. These almost horizontal beds, which have yielded a few imperfect plant remains, are thought to be the equivalents of the Dubrajpur beds of the Rajmahal area. Their outcrops cover a total area of only about 4 square miles, but on both Panchet and Biharinath hills the thickness of the beds can scarcely be less than 1,000 feet, and may be as much as 1,200 feet.

In the eastern part of the field, around Durgapur, are some soft, coarse, felspathic, pebbly sandstones, very similar lithologically to the supposed Dubrajpur beds further west but probably younger; some of these so-called Durgapur beds appear to be no older than Miocene[1].

The main complex boundary fault, which limits the coalfield to the south and west, has caused the Gondwanas to subside within the Archæans to a depth varying up to at least 9,000 feet in the vicinity of Panchet Hill. This southern fault is by no means a single unbroken displacement, but rather a series of large strike-faults *en échelon*. With local exceptions, the northern limit of the basin, in contrast to the southern, is one of natural deposition and is a trace of the uneven Archæan land-surface that existed in early Gondwana times. Just as the main Raniganj basin owes its preservation to the effect of the principal boundary fault to the south, so the trans-Adjai strip of Damuda sediments owes its survival to the agency of the large oblique strike-fault which follows the Adjai river, with a downthrow to the northeast. In addition to the dislocations mentioned above, there are many cross-faults, some of them of very considerable throw, others of only minor consequence, which complicate the northern boundary of the coalfield and in many cases continue southwards for a great distance within the higher Gondwana strata. Mr. Gee remarks that particularly in the case of certain of these northern cross-faults, the strata swing round markedly, almost parallel to the dislocations, so that the local structures include a succession of fractured monoclines following along the lines of the faults, with synclinals, pitching steeply southwards, in the adjoining areas.[2]

Regarding the age of the displacements Mr. Gee concludes that, from the evidence of the unconformity between the Panchet and supra-Panchet rocks, it is possible that minor faulting and folding commenced in early Gondwana times, but it is certain, on the other hand, that the major displacements, affecting as they do the Lower Gondwanas and supra-Panchets alike, took place at a later date, probably during Jurassic times.

Jharia.—The Jharia coalfield, which was not discovered till about 1858, lies west of the Raniganj basin and is separated therefrom by some 14 or 15 miles of Archæan gneiss. The Damodar, which passes across the southern part of the field but is not navigable, provides a valuable supply of sand for stowing purposes to those collieries which have adopted this economic method of working their seams. This field is much smaller than that of Raniganj, the Gondwana rocks exposed having a total area of about 175 square miles and being nowhere more than 12 miles in width and 24 miles in length from west to east.

The structure and disposition of the rocks are very similar generally to those pertaining to Raniganj, even to the presence of a small inlier of gneiss. Lying abruptly upon the Archæan gneiss, the Gondwanas comprise Talchir and Damuda sediments similar to those found in the Raniganj area, but no younger formations. The southern boundary is a long, nearly straight fault, and the strata show a general dip towards this boundary where they are abruptly cut off. The throw of the boundary fault is less than that of the corresponding feature in the Raniganj basin. Both at the eastern and western ends of the field, Dr. Fox records irregularities suggestive of compression on a line connecting the two localities, amounting perhaps to overthrusting in the west; at the eastern locality a horst of gneiss indents the Gondwana boundary. There are several strike faults within the basin, and these are described as "sag" faults which begin suddenly, increase when traced laterally for a mile or so to a considerable throw and die out a little further on. Such faults, which are common in the northern and central parts of the field, are normal tensional displacements, evidently related to those forming the southern boundary. A few cross faults are recorded. In the neighbourhood of the gneissic inlier, the faults of the coalfield become continuous with quartz reefs in the gneiss. In Dr. Fox's opinion, many of the quartz reefs seen in the gneiss along the Grand Trunk Road a few miles north of the Jharia basin mark fault lines which have become filled with quartz.

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[1] E. R. Gee. *Mem.* LXI, 70 (1932).

[2] *Mem.* LIX, 85 (1934).

The Talchirs are well exposed in the northwestern and western parts of the field attaining a thickness of quite 800 feet, of which about 50 feet near the base consist of a boulder bed of re-sorted moraine material. The rest of the stage is made up of argillaceous sandstones, buff-coloured arenaceous clays, dark greenish shales with calcareous nodules, and typical greenish-buff needle shales[1]. Throughout the greater portion of the northern border of the basin, the Talchirs occupy but a narrow strip of country seldom more than half-a-mile across, and in the northeast of the field are overlapped by the Barakars. The glacial pavement, mentioned in the previous chapter, occurs to the north of Suranga. No fossils have been recorded in the Talchirs of this area.

The Damudas, which are described by Fox as clearly separable from the Talchirs, are seen to overlap completely the latter rocks in the extreme east of the field and to rest upon the gneiss. The Damuda series consists of the following :

3. Raniganj stage	2,200 feet.
2. Ironstone Shales	700 ,,
1. Barakar stage	3,000 ,,
	5,900 ,,

Comparing these figures with those of Raniganj, it would appear that whilst the lowest stage has increased in thickness, the two younger stages show marked decreases ; the Ironstone Shales group, however, is of somewhat artificial individuality, and the Raniganj stage may have suffered reduction in the Jharia area by the denudation of some of its highest horizons. No animal relics have been found in the Damudas of Jharia, but plant remains are common throughout.

The Barakars occupy the greater portion of this field, and are shaly on the whole, with thick felspathic grits and sandstones near the base. Coal is found throughout, the largest seams lying mostly near the base. Nearly all of it, especially that of the higher seams, has caking propensities. Many of the Barakar seams of Jharia provide some of the best steam and caking coals obtainable in India. Most of the hard coke produced is used by the iron-smelting industry and for foundry purposes ; the manufacture of soft coke may have a great future provided it can compete successfully with the use of dried cow-dung as a domestic fuel throughout the country. Many of the Jharia seams have been rendered locally worthless by sills and dykes of mica-peridotite and dolerite.

The Ironstone Shales are not nearly so well marked a group as they are in Raniganj, and ironstones are less abundant.

The Raniganj stage is distinctly poorer in coal seams, both in number and thickness, in Jharia than it is in Raniganj. This has been attributed by Messrs. Medlicott and Blanford to the absence of the higher portions of the stage which, if they were ever present at all in the Jharia area, appear, in the opinion of these two observers, to have been removed by denudation. On this assumption, the most valuable coal seams of the Raniganj field are unrepresented in Jharia, where comparatively few seams have been traced above the Ironstone Shales. Dr. Fox, on the other hand, correlates the highest Raniganj horizons in Jharia with the highest Raniganj horizons in the Raniganj field. Whichever view may be the correct one, the rocks of the Raniganj stage in Jharia have been much disturbed and are in general inclined at angles too high for profitable mining.

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[1] C.S. Fox. *Mem.* LIX, 103-104 (1934).

Up to the year 1934, the total output of coal from this field was of the order of 250 million tons. Since 1908 this coalfield has provided one half of the total production from Indian mines. The reserves of coal to a depth of 2,000 feet in 1934 were estimated to amount to nearly 20,664,000,000 tons.

Bokaro.—The river Bokaro, which traverses the basin from west to east before joining the Damodar, has furnished the name for the next coalfield, in the eastern portion of which the two streams unite. Like the Ramgarh and Karanpura fields, it occupies low valley country, whilst the ground both to the north and south is much higher and composed of Archæan metamorphic rocks. This long narrow strip of Gondwana strata, roughly 40 miles from east to west and less than 7 miles from north to south, lies in a belt of trough-faulting, and covers an area of about 220 square miles. The eastern end of the field is within two miles of the tongue of Talchirs which extend westwards from the Jharia basin. The deepest part of this coalfield lies beneath Lugu Hill, which is also the highest point attained by the Gondwanas of this tract. The difference in level, therefore, between the relatively flat country of east Bokaro, occupied by Middle Barakar beds, and the presumed Mahadeva summit of Lugu Hill—a difference of not less than 2,500 feet—gives some idea of the extensive denudation which the rocks of the area must have suffered[1]. The top of Lugu Hill is above the general level of the adjacent Hazaribagh plateau.

This field occupies in the main a trough-like depression between two parallel faults, one of which forms part of the northern boundary, and the other the greater portion of the southern ; about half of the northern boundary, however, is a natural depositional one, whilst the southern fault trespasses for a considerable distance within the Gondwana outcrop, rocks of the Damuda series occurring for some distance to the south of the fault. These large faults run nearly east and west in this field, but smaller faults with a general NNW-SSE direction are met with and appear to correspond with the NW-SE faults of the Raniganj field ; they are evidently of later date than the great EW faults which they dislocate in places. On the whole, the rocks of the Bokaro area are more disturbed than those in the fields to the eastward.

The thicknesses of the Gondwana subdivisions exposed in this field have not yet been determined ; these subdivisions are :

? Mahadeva (? Dubrajpur) ;
Panchet ;
Damuda { Raniganj ;
  Ironstone Shales ;
  Barakar.
Talchir.

The two extremities of the field consist almost entirely of Barakars, while higher beds are exposed in the centre. The Talchirs are but poorly developed, their principal exposure occurring on the western edge of the basin. A few small patches are found along the northern border and the same beds form a narrow margin for some four miles on the northeastern boundary. They are overlapped in many places by the Barakars, which rest directly upon the Archæan throughout at least half of that portion of the boundary which does not consist of a fault. The Talchirs are of the usual character, and the boulder bed is well developed, boulders being found occasionally in the upper members of the stage as well as near the base.

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[1] C. S. Fox. *Mem.* LIX, 120 (1934).

The Barakars occupy about three-quarters of the whole field. A conglomerate of small quartz pebbles at their base is well marked, and they contain numerous coal seams, some of them of considerable thickness. Most of the coal is of inferior quality, but the principal seam—the Kargali—is in several places over 100 feet (in one place 125 feet) thick and of good quality. Above the Kargali is a 12-feet seam, and below it are the Bermo and Karo seams, 40 feet and 80 feet thick respectively. The reserves in east Bokaro in the Kargali seam alone are upward of 500 million tons of good coal, most of which is of good caking character and, if cleaned, capable of yielding metallurgical coke. Coal prospects in west Bokaro are less promising, but this part of the field has not yet been thoroughly exploited. Dr. Fox has called attention to the fact that in three of the Damodar valley coalfields—Jharia, Bokaro and Karanpura—the eastern areas appear to contain far more attractive seams in the Barakar stage than are found in the same strata in the western tracts of the same fields ; this seems to be due largely to the fact that the seams are far less disturbed by faults and are better exposed in the eastern areas of each field and have thus received greater attention. The annual production from Bokaro between the years 1928 and 1930 inclusive exceeded 2 million tons.

Ironstones occur in the Barakars and there is no marked line of division between this stage and that of the Ironstone Shales. At the same time, the Ironstone Shales are more fully developed in this field than in any other, being 1,500 feet thick. They present precisely the same character as they do in the Raniganj field, and pass downwards into the Barakars from which they are distinguishable only by mineral characters. The Ironstone Shales, besides intervening between the Barakars and the Raniganj beds east of Lugu Hill, occur in a small tract in the northwest of the field where both they and the overlying stage are let in by faults, and also occupy several tracts in the southwest of the field south of the great boundary fault. A few other patches of these shales are observable, but they are small and unimportant. The ironstones themselves are described as rather siliceous and inferior in quality to the bands associated with the Barakar stage.

The Raniganj stage covers a tract of about 14 square miles to the east of the Panchet outcrop around Lugu Hill, and is again found in the northwest corner of the field, resting on the Ironstone Shales with a well marked unconformity and abruptly overlapping them in places. It contains few workable coal seams.

The Panchets occupy a tract in the middle of the field ; Lugu Hill is entirely surrounded by these beds and the plinth of the hill itself is composed of them. They consist of the usual micaceous sandstones, green silty beds, and red clays. Their unconformity to the Damudas is striking, for, although they rest on the Raniganj beds to the eastward, within the short distance of about a mile they completely overlap both the Raniganj and the Ironstone Shales north of Lugu Hill, and to the west they rest upon Barakar beds. In places the Panchets can be seen dipping at an angle of 15° and resting upon Damuda strata inclined at from 25° to 30°, a relationship which points to the folding and denudation of the Damudas prior to the deposition of the Panchet sediments.

The whole of the upper portion of Lugu Hill is made up of coarse conglomerates, grits and sandstones, much impregnated with iron, and having generally a reddish colour ; they are described as precisely resembling the beds of Panchet Hill in the Raniganj field. The rocks of the hill are nearly horizontal, and the slopes are so covered with pebbles and other detritus that the relations between these beds and those of the underlying group are concealed. It has been suggested that these higher beds may be the equivalents of the Dubrajpur beds of Rajmahal or the Mahadevas of the Satpura region.

Dykes of dolerite and of mica-peridotite are nearly as common in this field as they are in that of Jharia, and there is possibly no area in India which offers better facilities for the study of the baked and fused strata associated with the burnt outcrops of coal seams than that between Kargali and Sawang. The intrusions traverse all the Gondwana groups except the supposed Mahadevas or Dubrajpurs.

Ramgarh.—The Ramgarh coalfield lies due south of the Bokaro area, the shortest distance between the two Gondwana outcrops being only 3½ miles. This field derives its name from the old town of Ramgarh on the Damodar river, near the western extremity of the area, and is of irregularly triangular shape, its greatest length from west to east being 14 miles. It is broadest in the east where it measures about 8 miles from north to south, diminishing rapidly in breadth to the westward until it is not more than a mile across ; beyond this narrow portion, however, it continues for another 5 or 6 miles to the west with a breadth of from 1 to 2 miles. The whole area is about 40 square miles, and is traversed throughout its entire length by the river Damodar.

As in the Raniganj and Jharia basins, there is in this small area a general dip of the rocks southwards and an abrupt and faulted southern boundary. The direction of the western portion of this boundary is nearly due EW, as in the Bokaro field, but in the eastern portion the strike turns to ESE. The western part of the field is much cut up by cross faults running NNW-SSE ; these dislocations, like those in the Bokaro field, appear to be of later date than the EW faults.

No rocks younger than the Raniganj occur in the Ramgarh basin. The subdivisions exposed, with their approximate thicknesses, are as follows :

Damuda	Raniganj	?
	Ironstone Shales	1,200 feet.
	Barakar	3,000 ,,
Talchir		850-900 ,,

The Talchir rocks occupy a considerable area in the extreme north of the field, and they again occur on the eastern boundary, but they are overlapped by the Damudas throughout the greater portion of the eastern and northern borders of the Gondwana area, and they only appear in two small patches along the north-western boundary and in another patch at the extreme western end of the basin. In one spot, they are found on the southern fault, which traverses them at a place where its throw is very small. The boulder bed is well developed to the north.

The Barakar is the only stage in the field which is developed over a large area and presents an unusual thickness. Its beds are of the same character as they are in the neighbouring coalfields, consisting of grits and sandstones, with conglomerates of small white quartz pebbles towards the base. There are several seams of coal which, in the eastern part of the area, are generally thick and gently-dipping, variable in quality and much interbedded with carbonaceous shale. In the western parts, the coal is of workable thickness and better quality, but the seams dip at steeper angles and the coal is frequently crushed and cut off by faults.

The Ironstone Shales are much less carbonaceous than they are in the Raniganj field, and consist of shales and sandstones, with a few bands of poor-quality clay ironstone. The area occupied by the stage does not exceed half a square mile. With the exception of a small outlier on the Damodar in the east of the field, the Ironstone Shales are confined to a tract a little east of Ramgarh, where they intervene between the Barakar and Raniganj beds. This tract, the only portion of the Ramgarh area in which the Raniganj stage is found, is surrounded by faults on all sides. These Raniganj rocks, covering nearly a square mile, are much disturbed by faulting, and no coal seems to have been detected among them.

The field is not free from dolerite dykes and possibly from mica peridotite intrusions.

Karanpura.—The two Karanpura fields—North Karanpura and South Karanpura—conclude the list of the Damodar valley coal basins. They lie due west of the Bokaro and Ramgarh fields and in close proximity to them, only a mile intervening between the Bokaro and North Karanpura tracts, and about 2½ miles between the field of Ramgarh and that of South Karanpura. South Karanpura forms a small separate basin connected at one point with the North Karanpura outcrop by a short strip of Talchirs, but separated therefrom elsewhere by a narrow belt of gneiss.

The Karanpura tract of Gondwanas is complicated by faulting and other irregularities. The greater part of the portion spoken of as North Karanpura forms a main central basin with a general E.-W. strike. The outcrops of the Damuda stages of this basin, instead of tailing out westwards in a regular manner, are all repeated, partly by the aid of faulting, in what might be described as a small subsidiary basin west of Burgaon. In the southwest corner of the North Karanpura tract is a better defined subsidiary basin which evidently belongs to the axial line of the South Karanpura field. Each corner of the blunt eastern end of the North Karanpura outcrop also forms an incomplete subsidiary syncline; the more northerly of these is sliced with faults, while the more southerly or Rikba half-basin is in a line with the Bokaro basin. Some first-class and a greater number of second-class coal seams have been proved in the Karanpura fields. The total quantity of both first and second class coal down to a depth of 2,000 feet has been estimated by Dr. A. Jowett to be between 5,000 and 10,000 million tons. Thick good-quality seams which can be quarried characterise the southern field. Both dolerite and mica peridotite intrusions are met with in both coalfields.

South Karanpura.—The South Karanpura field is 23 miles in length from east to west, its average breadth being about 4 miles; the area occupied is about 75 square miles, 4 or 5 of which, however, are composed of an inlier of gneissic rocks near the eastern end. The Damodar river traverses the field from east to west and the centre of the field lies to the southeast of North Karanpura. The southern boundary consists of the usual line of faulting, which cuts off all the sedimentary rocks, none of the latter being found on the southern side of the throw. The general dip is, as in other fields, to the south.

The rocks exposed include:

Damuda { Raniganj;
Ironstone Shales;
Barakar.
Talchir.

According to Dr. Jowett, neither the Panchets nor the Mahadevas are present in the South Karanpura tract. The Talchirs are seen in three or four places as short and extremely thin fringes to the Barakar outcrop along its northern border and round its eastern termination. In one place they appear to have been recognised on the line of the southern boundary fault[1]. Elsewhere throughout the northern boundary, the Barakar stage rests directly upon the Archæan. No Talchirs are exposed around the gneissic inlier, although the greater part of the boundary is one of natural deposition. The Barakar beds occupy nearly three-quarters of the area, and appear to contain more coal than they do in the other fields of the upper Damodar Valley. Some bands of rich ironstone occur in this stage. The two higher Damuda stages are poorly developed. The main exposure of these beds lies within the Barakar outcrop, but its southern boundary is for the most part a line of faulting more or less parallel to the southern faulted boundary of the basin as a whole. Westwards the Raniganj beds overlap the Ironstone Shales and rest on the Barakars.

North Karanpura.—Covering an area of over 470 square miles, as it does, North Karanpura is second only to Raniganj in size among the coalfield basins of the Damodar valley. Its maximum length from east to west is nearly 40 miles, while the width across the middle portions of the basin is about 20 miles. The Damodar river runs for many miles through the southwest portions of the field.

The Gondwana formations present, with their approximate thicknesses, so far as these have been ascertained, are as follows:

Mahadeva		300 feet.
Panchet		?
Damuda	Raniganj	?
	Ironstone Shales	600 feet.
	Barakar	1,500 ,,
Talchir		400 ,,

The shape of the exposure is nearly elliptical, and the field has more of the character of a structural basin than any other tract of Gondwana rocks in the Damodar valley. The highest beds occupy the middle of the field, and the lower groups crop out to the south as well as to the north of them. To the eastward the beds are cut off on the south by an E.-W. fault, which brings up to the surface the belt of gneissic rocks incompletely intervening between this field and that of South Karanpura. To the westward the field extends much farther to the south than it does to the eastward, and the southern boundary here appears to lie along a westward continuation of the line of fault which forms the southern limit of the South Karanpura field.

In this field an important change has taken place in the relations of the different rock groups to each other. In the Raniganj coalfield, the Raniganj stage is the most developed, while three groups, all of considerable thickness, intervene between the Barakars and the so-called Mahadevas. All these intermediate groups thin out greatly to the westward, and their diminution in thickness is continued in the field under consideration. Still farther to the west, no rocks intervene between the Barakars and a thick group of sandstones and conglomerates resembling in mineral character the supra-Panchet rocks of the Damodar valley and the Mahadevas of the Satpura hills.

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[1] *Mem.* LII, Pl. 14 (1925).

The Talchirs in North Karanpura occupy a total area of no more than 9 square miles. Of the two largest patches, one occurs at the extreme north of the basin, while the other crops out in the south, joining the Gondwanas of North Karanpura to those of the South field. There are numerous minute outcrops along the irregular eastern margin of the field and around a small gneissic inlier at this end of the basin. Throughout by far the greater part of the unfaulted portion of the field margin, the Barakars rest upon the gneiss. The beds consist of the usual shales and fine-grained sandstones with the boulder conglomerate at their base. One of the best known sites where well preserved plant remains occur in the Talchirs of India is that near Rikba.

Accompanying some of the outcrops of Talchirs, especially the two largest, and intervening between these rocks and the main bulk of the Barakars, are pebbly sandstones, flagstones and a few thin coal seams, which are reminiscent of the Karharbari beds of Giridih. The Barakars as a whole cover nearly one half of the basin, and almost completely surround the area occupied by the higher formations. They are much less shaly and contain more sandstones than the same beds in the more easterly basins. Several coal seams occur, some of them of substantial thickness; some of the thinner seams are said to be of good quality. Throughout long sections of the Barakar outcrop there is evidence of the presence of coal in the baked and fused rocks where seams have been on fire along their outcrop; the destruction of surface coal in this way has been considerable. Such superficially injured seams, however, are found intact at a relatively shallow depth, and experience has shown that the combustion of such outcrops with the evolution of so much heat generally means that the quality of that particular coal is good. Dr. Jowett has noted seams of 90, 72, 59, 53, 46, 37, 35, 30 and 28 feet, and others between 12 and 24 feet. The thickest and most important seam is found about 300 feet above the base of the Barakars, but the quality varies and shale partings make up a considerable proportion. Some rich ironstones are found in the Barakar stage, the best hæmatite containing as much as 60 per cent. of iron.

The Barakars of this basin have been divided into three sub-stages as follows:

3. Shales and shaly sandstones with thin coal seams and, at the top, ironstones.
2. Predominant sandstones, less coarse than those below, coal seams of moderate thickness, and several beds of iron ore; no conglomerates.
1. Conglomerates of small quartz pebbles, coarse sandstones and grits, with some thick coal seams.

As usual, the coarse grits and pebble beds form low hills, in contrast to the more or less level country of the higher Barakar horizons, the Ironstone Shales and the Raniganj stage. Some of the felspathic sandstones of the Barakars weather into peculiar little pitted depressions not unlike animal footprints. The relative thickness of different members of this stage varies greatly from place to place a bed of sandstone frequently changing in thickness within a short distance.

The Ironstone Shales are found in the northern and eastern portions of the field, where they form a narrow fringe, much interrupted by cross faults, to the Raniganj outcrop. To the west and south they are everywhere completely overlapped. This stage is represented in both the small subsidiary half-basins in the extreme east of the field. The shales of this area are described as paler in colour, more siliceous and much less carbonaceous than they are in the Raniganj field; the ironstones also appear to be somewhat less rich.

The Raniganj stage crops out in a band averaging some two or three miles in width and surrounding the Panchet and Mahadeva areas in the middle of the field; it is also present in the westerly repetition of the main basin, and in the three small subsidiary basins mentioned above. There is little in their mineral character to distinguish the Raniganj beds from the upper Barakars, and where, as in the western part of the field, the intervening Ironstone Shales are absent, it is difficult to draw a boundary line between the two stages of the Damuda. There are several coal seams but very few of workable thickness.

The Panchets of North Karanpura occupy a considerable tract around the hills of supra-Panchets or Mahadevas. The Panchet sandstones of this area are for the most part coarser and less micaceous than those of Bokaro. Red clays are common in the middle and upper portions of the series, but are not distributed in thick beds as they are in the Raniganj field; they are in fact thinly laminated and alternate with green micaceous clay.

Besides a few scattered outliers, the Mahadevas form the hills of Maudih (Mahudi) and Sathpahari in the centre of the field; they also occupy a small rise about three miles long near Ganeshpur in the westerly repetition of the main basin, as well as Gerwa (Malhan) Hill which forms the centre of the small subsidiary basin in the extreme southwest of the Gondwana area. Maudih is a plateau about 11 miles in length from east to west and 5 across from north to south. The rocks consist of massive sandstones, occasionally conglomeratic, with rare intercalations of hard, red, flaggy and shaly beds. The pebbles in the sandstones are very characteristic, being sub-angular and iron-stained. In spite of the usual apparent concordance between the Panchets and Mahadevas, the overlap of the former by the latter is proof of actual unconformity; in one or two sections clear angular unconformity can be seen.

Both mica peridotite and dolerite intrusions are met with in this coalfield; the latter at any rate are said to be less abundant than they are in the more easterly Damodar fields. Further to the westward no dykes are found in the coalfields until the area of the Deccan Trap is entered. Faults of any size are less prevalent than they are in the other Damodar fields. It has been suggested that the paucity of dykes and large faults indicates in the one case that the Karanpura area is near the limit of the volcanic outbursts of Rajmahal times, in the other case that the principal dislocations in the more easterly Damodar fields were connected with the disturbances which preceded the outpouring of the Rajmahal traps.

Three miles west of the extremity of the Karanpura field occur some sandstones belonging to the Gondwana system on an isolated hill known as Madaghir.

Chope.—The Chope area, in the bed of the Mohani river, probably the smallest tract of coal-bearing Gondwana rocks in India, is of peculiar interest from its position on the top of the Hazaribagh plateau, some 2,000 feet above sea-level. It lies about six miles north of the northern edge of the Karanpura coalfield, and is a repetition in miniature of some of the characteristic features of the Damodar coal basins. It is sub-triangular in shape, about 1½ miles in extreme length from west-by-north to east-by-south, and rather less than a mile broad in a direction at right angles to the length. It consists of Talchir and Barakar rocks, dipping to the southward, with an anticlinal dome in the centre exposing an inlier of Talchirs. Along its southern border, this Gondwana tract is cut off by a fault running west-by-north to east-by-south. The Talchirs skirt the field and consist of fine greenish sandstones with the boulder bed. Only a small thickness of Barakars is exposed but it includes a 4-foot seam of shaly and inferior coal.

Itkuri.—The Itkuri (Itkhori) coalfield, about 25 miles north of the Karanpura field, lies further down the Mohani valley than Chope. It is 15 miles long from east to west, but very narrow, being nowhere more than 2 miles broad. The whole area consists of Talchir beds with the exception of one small patch, about half a square mile in extent, occupied by Barakars. The boundaries are mostly normal, a small fault cutting off the single outcrop of Barakar beds to the northeast and bringing up Archæan rocks against it. The Barakars contain three seams of inferior coal.

Kunda, Amjhar and Kisgo.—Three or four small outliers of Talchir rocks are known to occur 30 miles northwest of Giridih, in the valley of the Kunda. Another outlier occurs south of Amjhar, and yet another a mile southwest of Kisgo.

Sherghati.—A small exposure of Talchir beds is known in the bed of the Murhar river, at the small village of Gangti, 20 miles southwest-by-west of Sherghati. The only interest attaching to this outcrop is its occurrence on the edge of the Gangetic alluvium, and the consequent suggestion that Gondwana rocks may exist beneath the alluvial deposits in this part of the Gangetic plain.

Daltonganj.—The Daltonganj coalfield, about 50 miles west of Hazaribagh town, is traversed by the North Koel river, a tributary of the Son. Coal was first worked in this area from 1842 to 1848, and later by the Bengal Coal Company whose colliery at Rajhara was wrecked during the Great Mutiny of 1857. Previous to 1901 (when railway communication was established down the Son valley to the main line of the East India Railway), the coal was sent by boat down the North Koel and Son rivers to the Ganges. The field is a long irregularly shaped tract, with very tortuous boundaries; it is about 50 miles in length from east to west, and varies in breadth from 1 to 8 miles, its total area being 200 square miles. Inside the basin, whose boundaries appear to be natural ones, several inextensive inliers of gneiss occur. Around the field are scattered some small outliers of Talchirs.

The only formations represented are the Talchirs and Barakars. The former covering more than four-fifths of the area, are about 500 feet thick, and comprise the usual rocks, sandstones being more prevalent than shales, whilst the boulder bed is well developed. The Barakars are restricted to a tract nearly 10 miles in extreme length from northwest to southeast, and 4½ miles broad, with an area of 30 square miles. The lithological character of the stage is different from what it is in the Damodar fields, the sandstones, which form the bulk of the formation, being friable, slightly calcareous, more frequently yellow than white in colour, composed of alternating fine and coarse layers, and very current-bedded. The general appearance of these beds is intermediate between typical Barakars and typical Raniganj sandstones, and it should be borne in mind that this field lies beyond the region within which the Raniganj stage has been recognised. Seams of coal are few in number and of indifferent quality; the evidence of plant remains has been adduced as indicative of a Karharbari age for the seams in the neighbourhood of Rajhara, where one of the seams is as much as 29 feet thick.

No mica peridotite has been met with in the coal workings, and there is only one dolerite dyke in the field.

Sathbarwa.—Talchirs have been observed at Sathbarwa, a halting-place 16 miles southeast of Daltonganj, on the road to Ranchi, intermediate in position between the Aurunga, Hutar and Daltonganj basins.

Several other small basins of Gondwana rocks are known to occur in the Palamau country.

Aurunga.—The Aurunga river gives its name to the Aurunga coalfield through which it flows northwestwards to join the North Koel. The eastern limit of this field is about five miles west of the western end of the North Karanpura outcrop. Although not part of the present catchment area of the Damodar river, the Aurunga coalfield was an integral part of the Gondwana sedimentation of the Damodar valley. The synclinal nature of this basin has been greatly complicated by E.-W. and NW-SE faults, and the southern boundary is almost entirely one of natural deposition. The total area of Gondwana beds is 97 square miles. Excluding the few scarped hills which mar the outliers of Mahadevas, the country is flat or gently rolling.

It is only in places that the Talchirs peep out from below the Barakar beds, and around the greater part of the unfaulted margin of the field the latter overlap the former on to the gneiss. The thickness of the Talchirs exposed is given by Dr. Ball as 300 feet. The same authority quotes 1,500 feet as the maximum thickness of the Barakars, 1,000 feet as that of the Raniganj, 700 feet as that of the Panchet, and 1,000 feet as that of the Mahadeva. It has, however, been found difficult to mark off the Raniganj beds from the Barakars and to separate them from the Panchets. The Barakar beds are unusually ferruginous and are consequently not easily distinguished from the overlying Mahadevas which are largely developed. The Ironstone Shales have not been recognised. The Mahadevas appear to rest discordantly on the rocks below, and in the western part of the field lie directly upon the Barakars. A few rare coal bands are to be seen in both the Barakar and Raniganj stages, but the coal is of very poor quality, and it is only by courtesy that the area could be called a coalfield. An interesting feature of the Aurunga area is the apparent absence of basic or ultra-basic igneous intrusions.

An outlying strip of the Talchirs, including the boulder bed, is seen a few miles west of the Aurunga outcrop, stretching W.S.W.-wards for two or three miles.

Hutar.—Ten miles or so west of the nearest edge of the Aurunga outcrop is the commencement of the Hutar basin, lying on the same line as the Aurunga, Karanpura and Damodar valley fields. A little under 80 square miles in area, this field is traversed from southwest to northeast by the Koel river and, therefore, like the Aurunga, belongs to the present catchment area of the Son, though obviously another relic of the old Gondwana valley which coincided lower down with the Damodar.

A large part of the northern boundary of this tract is faulted, and a prominent E.-W. fault, characterised in one place by a hot spring, crosses the more southerly portion of the Gondwana outcrop; otherwise, most of the border appears to be one of natural deposition.

By far the greater part of the area is taken up by the Barakar stage, which is fringed interruptedly by the Talchirs. From fossil evidence, some of the Barakar beds are suspected of corresponding to the Karharbari sediments of the Giridih field; the topmost horizons of the Barakars are described as somewhat abnormal though too coarse in character for typical Raniganj beds. Several seams of coal are present, some of them of good quality. The only other Gondwana formation represented is the Mahadeva, which occurs only in the western part of the field and in a small outlier stretching westwards from Bitwa Hill.

Tatapani-Ramkola.—Still along the Damodar valley line and again belonging to the Son catchment area is the Tatapani-Ramkola coalfield, the eastern extremity of which is about 15 miles west of the western limit of the Hutar outcrop. It lies on a floor of Dharwar rocks in north Sarguja, between the Kanhar and Rehar (Rer) rivers, and is but an easterly prolongation of a very large spread of Lower and Upper Gondwana rocks, which stretches westwards through western Sarguja, across southern Rewah into the eastern borders of Jubbulpore. This large tract, covering so much of Sarguja and northeast Bilaspur, is the termination not only of the Damodar valley line of Gondwana basins but also of the Mahanadi line of similar outcrops ; it includes several coalfields, to which attention will be given after the Mahanadi line of Gondwana outcrops has been described. The central portion of the Tatapani-Ramkola area is drained by the Morne which flows westwards and joins the Rehar. The eastern end of the field is traversed by the Sendur, a tributary of the Kanhar.

Confining present attention to the Gondwana rocks east of the Rehar, the total area is about 800 square miles, of which more than two-thirds consist of Mahadevas. The latter occupy central hilly country and divide the Lower Gondwana outcrop into two bordering but very irregular belts. The general synclinal character of the field has been much disturbed by faulting and the only extensive unfaulted section of the boundary is that at the eastern end, where there is a marginal outcrop of Talchirs. This tract of Gondwanas has been preserved from denudation as a result of its subsidence between lines of more or less parallel faulting.

The Talchirs, which do not exceed 900 feet in thickness fill up hollows in the Dharwar schists which here form the floor of the syncline. Bedding is most irregular, beds thinning out and thickening very rapidly. Among the boulders of the boulder bed are some enormous blocks 30 or 40 feet in diameter, lying in a fine silty matrix.

The Barakars appear to lie unconformably on the Talchirs and overlap them on to the Dharwars. Griesbach speaks of a denuded surface of Talchirs in one place with old pot-holes filled with thinly laminated bluish-grey Barakar shales.[1] The thickness of this stage probably does not exceed 900 feet, but the upper limit, unlike the lower, is ill defined. The thinness of the coal seams, the poorness of the coal, and the isolated position of the area render it of little economic importance at the present time, but further investigations are desirable. The largest and best seams occur in the vicinity of the Morne river.

The Raniganj beds are claimed to be recognisable by their plant remains. They are described as remarkably rich in iron-ore bands or nodules and thin bands of ironstone shale. Petrologically they differ from the beds of the type area, conspicuously so in the absence of coal. They consist chiefly of white felspathic and gritty sandstones, white shales with numerous plant remains, thick beds of clay ironstone, ferruginous sandstones with nodules of iron ore, and ironstone shales ; the last are well seen in the Sendur river section. The approximate thickness of this stage is probably not more than 1,300 feet.

All the sandstones, grits, clays and shales between the so-called Raniganj and the typical Mahadeva beds have been included by Griesbach in the Panchets, which are estimated to be 1,200-1,500 feet in thickness in the Tatapani sections at the eastern end of the field, but which thin out considerably westwards. The commonest rock is a red clay. Several characteristic plants have been noted in the Panchet sediments.

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[1] *Mem.* XV, 143 (1880).

The Mahadevas form bold, often perpendicular escarpments, and plateaux from 2,000 to 3,000 feet above sea-level. Their thickness is probably nowhere more than 800 feet. Nearly the whole formation is composed of thick, extensively jointed beds of reddish brown, ferruginous, gritty sandstone, generally current-bedded and remarkable for their hard ferruginous partings; these parting cut up the beds in a singular manner and, after the rock has undergone disintegration, remain standing like thin walls and long ridges in the mass of the sandstone. The Mahadevas may overlap younger rocks but this requires confirmation they are in places faulted against all the other rocks—Archæan, Talchir, Barakar, Raniganj and Panchet.

Dykes and intrusive sheets of trap have penetrated all rocks from Archæan to Mahadeva. Denudation has exposed large sheets of this trap east and south of Ramkola; in the latter region these sheets can be seen to have pushed their way for considerable distances between the Barakars and the overlying Mahadevas. The largest patch of sills is connected with a large dyke which traverses the Mahadevas for several miles.

IV.—MAHANADI AND BRAHMANI VALLEYS.

The enormous central tract of Gondwana beds already mentioned extends southwards into the northern portion of Bilaspur, beyond which it gradually contracts in width southeastwards into the line of basins along the Mahanadi and Brahmani valleys to the vicinity of the Orissa coast at Cuttack and Puri, by way of the Korba, Raigarh-Hingir and Talcher coalfields. Along this line, however, the Gondwana tracts are less definitely separated from each other than they are along the Damodar line. There is a wide gap between the Athgarh and Talcher exposures, but the former consists entirely of Upper Gondwana beds, and the latter is separated by only a very short distance from the long narrow tongue of Talchir rocks which connects with the Raigarh-Hingir coalfield. The areas to be considered under this heading are:

1. Athgarh;
2. Talcher;
3. Hingir;
4. Korba-Dharmjaygarh.

Athgarh.—The Upper Gondwanas of the Athgarh tract, whose nearest point is about 30 miles from the coast, have already been described. Though coal is reported to have been found near Sideshar Hill, some four miles west of Cuttack town, his does not seem to have been confirmed, and no trace of Lower Gondwana beds has been detected in the exposure. It is of course possible that the Lower Gondwanas have been completely overlapped by the Upper, but this is problematical and has never been proved by boring. A dyke of basalt near Sideshar Hill has intruded the Upper Gondwanas of this area.

Talcher.— Named after the State of Talcher, the Talcher coalfield lies almost entirely in the valley of the Brahmani river, which discharges into the Mahanadi delta northeast of Cuttack. From a point to the southeast of Talcher town this outcrop of Talchir, Damuda and Upper Gondwana rocks stretches westwards for 70 miles across Talcher State, the Angul district, and the States of Athmallik and Rairakhol, to terminate at Rampur, and has a maximum breadth of a little over 18 miles; it has an area of something like 700 square miles, and lies on a floor of Archæan gneiss traversed by dykes of granite and diorite.

The northern boundary is abrupt and faulted throughout. The southern boundary is for the most part also a fault, and the field has every appearance of having been preserved in the trough between these two lines of dislocation. The northern fault is marked by quartz veining and fault breccia, and in one or two cases divides into branches. In the eastern portion of the field, the general dip is north, increasing in magnitude near the faulted boundary, but extensive rolls are observable throughout this part of the field ; in the west, the whole area is occupied by nearly horizontal beds belonging to the Upper division. The groups represented are :

Mahadeva ;
Damuda { Kamthi ;
Barakar ;
Talchir.

The Talchirs, which have a maximum thickness of 500 feet, occupy the southeast corner of the field ; they reappear between the branches of the fault along the northern boundary, and are represented in the extreme west of the field where they project in typical tongue-shaped extensions occupying old hollows in the Archaean floor. This field is the type locality for the series, and the usual constituents—boulder beds, shales and sandstones—are well developed and characteristic. Traces of annelids or molluscs as well as a few plant remains have been found in these beds.

The Damuda series appears to be represented by the Barakars and the Kamthi (Raniganj). The latter were originally included with the Mahadevas, but some of the beds in the western portion of the field show every indication of being identical with the Kamthi series of the neighbouring Raigarh-Hingir area. The Barakars cover a large tract in the eastern portion of the field, where they stretch almost from the northern border to the southern. Westwards they are usually overlapped by higher beds, but are claimed to be present at one locality in the extreme west. These beds are distinctly unconformable to the Talchirs, and consist of white felspathic sandstones, coarse grey and brown grits, blue and carbonaceous shales, and some beds of coal. The coal is dull and frequently shaly, with a low ash but high moisture content, the latter feature rendering it non-caking.

The higher beds are unconformable to the Barakars, the discordance being not only indicated by overlap but actually seen in one or two sections. The rocks resting upon the Barakars consist of yellow and white sandstones with purple clays and have some resemblance to the Upper Kamthis near Chanda, as well as to some of the Panchet beds in the Damodar valley. Near Patrapada these beds attain a thickness of at least 600 feet, and appear to be more disturbed than the conglomerates and grits of the supposed Mahadeva series which rest upon them. Similar sandstones and clays are found in other parts of the field and, although no fossils have been found, they have been referred with some probability to the Kamthi, a series which is exposed in the Mahanadi valley farther northwest.

The beds forming the higher portions of the hills, in the western part of the Talcher field, consist of grits and conglomerates containing pebbles of gneiss, quartzite and sandstone ; some of the sandstone fragments closely resemble Talchir sandstone but may be derived from certain Vindhyan beds which are very similar in mineral character to some of the Talchir rocks. These conglomeratic upper beds are all more or less ferruginous, and contain bands of jaspery ironstone like those in the Mahadevas of the Satpura hills and in the Kamthis of Nagpur. From the apparent difference in the degree of disturbance suffered by the supposed Kamthis on the one hand and the overlying conglomerates on the other, it seems not unlikely that the latter represent some Upper Gondwana formation and may be referable to the Mahadeva. They exhibit some likeness to the Athgarh beds of Cuttack. To the south of Patrapada, this conglomerate series is about 800 feet thick.

The rocks tentatively assigned to the Kamthi and Mahadeva series occupy nearly two-thirds of the total area of the field, the principal outcrop occurring west of the main Barakar exposure and occupying the whole width of the field from the northern to the southern boundary. The same beds also occur in some small patches along the northern boundary of the Barakar outcrop ; the most important of these builds up a hill known as Konjiri northwest of Talcher town and overlooking the Brahmani.

No trap dykes have been found in the Talcher basin.

Hingir.—The Hingir or Raigarh-Hingir coalfield forms the southeastern extremity of the great central tract of Gondwanas. The southeastern portion of this area is sometimes spoken of as the Ib River or Rampur coalfield and is traversed by the Ib river, but it is nothing more than an integral portion of the large synclinal basin stretching from the vicinity of Sambalpur northwestwards for over 90 miles continuously into the Lower Gondwana area known as the Korba and Udaipur coalfield. The large Gondwana belt now being considered carries the town of Hingir, where it is rather more than 20 miles in width. Southeastwards, this belt terminates in a long narrow tongue of Talchir beds which extends for a distance of nearly 50 miles and ends within two or three miles of the Talcher field. The southwestern limit of the tract is straight and faulted for a long distance. The greater part of the floor of this basin is of Archaean gneiss, but for a short section of its northeast boundary it lies upon Dharwar rocks and to the west of Hingir it covers the margin of the great Chhattisgarh outcrop of Purana sediments. The northeastern margin is irregular, but that the town of Hingir lies within a basin is indicated by the disposal of the Barakars with respect to the central tract of Kamthis or " Hingirs " as they have been called.

The rocks found in the Hingir area consist of :

Hingir (Kamthi)	1,000 feet.
Barakar	?
Talchir	250 feet.

The Talchirs are for the most part confined to the southeastern border of the field and to the long strip which almost connects the outcrop with that of the Talcher field, but the beds make their appearance in other places from beneath the Barakar margin.

The Barakars occupy a considerable tract of country in the southeast of the field, and a narrow strip of these beds extends up each border therefrom. The northwestern part of the area is composed of another large outcrop which is continuous with a still larger outcrop stretching westwards to Korba and beyond. In many places the Barakars overlap the Talchirs and rest on the ancient floor rocks throughout considerable distances, as, for instance, along the northeast boundary of the field where such an overlap is seen for some twenty miles. The beds have a general low dip, not usually exceeding 10°, towards the faulted southwestern border of the field, but there is a considerable amount of rolling.

The Barakars of this area consist of felspathic sandstones and grits, shales and coal. About 500 feet of shaly beds with coal seams and occasional intercalations of sandstone are exposed in the Baisundar river, north of Hingir. Elsewhere the rocks exposed appear to consist chiefly of sandstones and conglomerates, the latter in some places containing occasional pebbles of red jasper. In the neighbourhood of Rampur, the Barakars contain much brown hæmatite in nests and regular bands. Of the coal seams known, the majority are thin and made up of a high-ash coal, but some are of workable quality and size.

The so-called Hingir beds consist of coarse ferruginous sandstones and conglomerates, and beds of red shale, but no carbonaceous bands. They form great masses of flat-topped hills, lying very nearly horizontal and consequently unconformable to the more inclined Barakars beneath them, and have been traced for fifty miles. In lithological character they resemble the Kamthis of the Godavari valley and have yielded plant remains all of which are of Damuda species not found in the Upper Gondwanas. Nevertheless, some of the beds have strong resemblances to Mahadeva sediments, and the higher coarse sandstones may perhaps belong to this younger group, for it has been found most difficult to divide up a mass of sandstones all similar in character and in which fossils are very rare. Whatever their precise age, the beds occupy the greater portion of the basin, the Barakars appearing from beneath them ; at the northern end of the basin they overlap the Barakars and rest upon the Archæan gneiss, while along the southwest boundary they are faulted against the Chhattisgarh Purana rocks. Through the upper sandstones of this younger group the streams have cut deep gorges, and the underlying rocks are frequently exposed in the bottoms of the valleys.

Only one trap dyke has been found in this area traversing the Barakars. A considerable quantity of laterite covers portions of the field.

A few very small outliers of Talchir beds have been noted to the south of the Hingir field and afford proof that the Gondwana system formerly covered a wider area. Of these outliers three, none of which exceeds a square mile in area, occur on or near the Ib river about 10 miles northwest of Sambalpur. A fourth is found just south of the Mahanadi and opposite to the junction with the Ib. Another is met with about 40 miles farther south on the Paljor river, a tributary of the Ong, and yet another on the Tel river, about 80 miles south of Sambalpur.

Kankani.—About twelve miles W.N.W. of Raigarh, a very small outlier, made up of about one square mile of Talchirs and one square mile of Barakars, lies partly upon the Puranas of the Chhattisgarh basin and partly upon gneissic rocks. This outcrop is barely two miles south of Kharsia Railway Station, and on its northern margin is situated the village of Kankani.

Korba-Dharmjaygarh.—In a northwest direction, the Hingir area is continuous with a larger Gondwana tract covering parts of central and eastern Bilaspur and the western margin of Udaipur State. The central portion of this tract lies between the Hasdo river on the west and the Mand river on the east, but both Barakars and Talchirs extend for 24 miles west of the Hasdo river to a point a little beyond the village of Pali. It is the Mand river which separates the Korba field from that of Hingir, but it is very probable that these two fields, instead of belonging to two individual synclinal basins, are integral parts of a single basin nearly 100 miles in length from northwest to southeast. It is quite possible that the two tracts are part of the same syncline and that the two separate outcrops have been isolated from each other by denudation due to cutting down of the Mand river and the uncovering of a broad belt of Barakar rocks along its valley. The field has been named after the small town of Korba on the Hasdo river, since it is the best known coal locality.

The Barakar outcrop slightly exceeds that of the younger rocks in size. Talchirs, sometimes filling up hollows in the ancient rock-floor, are exposed to an appreciable extent along the irregular western border, and a tongue of these rocks connects this part of the tract with the Gondwanas of Matin; elsewhere the usual small patches fringe the Barakar outcrop. In the Mand valley, the Barakars cover an area which cannot be less than 200 square miles, and contain several coal seams, some of considerable thickness and average quality. The Korba or Ib river portion of the Barakar outcrop is not much smaller in extent, and also contains coal seams which appear to be workable; Two thick seams, one of them 80-100 feet thick, appear to unite when traced laterally to produce a single seam 150 feet thick, though much of the coal is of poor quality and the seam includes a considerable proportion of shaly material.

Sandstones, either corresponding to the Kamthis of Hingir or belonging to the Mahadevas, are seen occupying an irregular central hilly tract between the two rivers. Trap of the Deccan suite caps some of these hills of younger sandstone in the northern portion of the field, including the hill of Ramgarh in southeast Sarguja.

V.—THE GREAT CENTRAL TRACT OF SARGUJA AND ADJOINING COUNTRY.

A brief consideration may now be given to the large central expanse of Gondwana beds which form the common termination of the Damodar valley basins and the Mahanadi-Brahmani line of outcrops. In this region the Gondwana sediments instead of being distributed in lines of detached basins, occur in the form of a very large continuous outcrop which extends from Jubbulpore on the west to the Tatapani coalfield of eastern Sarguja on the east; its northern limit stretches through Rewah a little south of the Son into the southern corner of Mirzapur, while to the south it extends beyond Sohagpur, through Korea to the Korba coal field already described. For a considerable distance this tract is 90 miles broad. Its rocks are said to have more in common with the Gondwanas of the Satpura region further west than with those of the Damodar valley. There is a general tendency to a northerly dip throughout the western part of the area, and again in the tract of Damuda rocks in Singrauli on the north side of the main Upper Gondwana outcrop. The northern boundary, swinging from W.S.W.-E.N.E. to W.-E., is for a considerable distance nearly parallel to the general course of the river Son, at a distance of from five to twenty miles south of the river. This boundary is very straight and of an abrupt character, and in places it is clearly a fault; along the line of junction are found fragments of both Damuda sandstones and the crystalline rocks which occur outside the Gondwana area to the north crushed together into a breccia. Higher rocks than the Damudas occupy the area to the northward in the western part of the Gondwana tract (Sohagpur) near the upper Son, but eastwards they extend past the Singrauli outcrop of Damudas which make their appearance abruptly on their northern border. The length from west to east of this broad continuous exposure of higher rocks, consisting for the most part at any rate of Upper Gondwana beds is about 200 miles. In the western part of the area these higher beds overlap the Lower Gondwana division and rest on Bijawar or Vindhyan rocks. The eastern and southeastern boundaries of the tract have already been described; on the south is a large spread of Talchirs resting upon the gneiss, whilst to the southwest the whole Gondwana system is gradually overlapped by the Deccan Trap scarp and the Lametas underlying the traps. These overlying rocks, where they first impinge on the area from the south, conceal only the lower members of the Gondwana system; the higher members extend farther to the west, while the highest of all locally, the Jabalpur group, forms a narrow and interrupted band cropping out at intervals round the northern margin of the Trap plateau of Mandla to Jubbulpore in the Narbada valley. The manner in which the Gondwana rocks disappear beneath the traps of this plateau confirms the conclusion that the former, to some extent at any rate, continue beneath the igneous rocks, and that the south Rewah and Satpura regions are parts of one continuous tract of Gondwana sediments.

The Talchir, Damuda, Mahadeva and Jabalpur series of the Gondwana system are all represented in the south Rewah area. It is quite possible that the lower portion of the beds mapped as Mahadeva may represent the Panchet; among these lower strata are the beds at Parsora, a village 6½ miles N.N.E. of Pali and about 18 miles W.N.W. of the town of Sohagpur (*vide* page 964). Forty miles to the northeast of Parsora and some seven miles south of Beohari are the beds of Tiki with their labyrinthodont remains and coniferous wood; they are regarded as the equivalents of the Maleri beds of the Wardha-Godavari region, and belong in all probability to the Mahadeva series.

The Talchirs occupy a large crescent-shaped tract on the Rehar river in south eastern Rewah and Singrauli, the length along the curve of the crescent being about 50 miles, with an average breadth of 5 or 6 miles. There are some smaller outcrops in the same neighbourhood along the northern boundary of the Gondwana tract, but the largest is only three or four miles across. The great expanse of Talchirs lies on the south side of the tract, where these beds cover several hundreds of square miles around Korea, one of the Sarguja States, and continue thence westwards until they disappear under the Lametas and Deccan Trap; this expanse of Talchir beds thus forms the southern margin of the south Rewah Gondwana basin.

The Damudas are represented by the Barakars throughout the region, and this group, being of economic importance on account of the coal it contains, has received more attention than the other beds. There are, however, good reasons for believing that higher Damuda horizons are present to the westward in Sohagpur and the Johilla area, and it is possible that there is discordance between the Barakars and these higher Damudas, though this is not certain. Some of the beds included with the Barakar were at one time thought to have much in common with the Karharbari stage of the Giridih field. Possible representatives of the Raniganj have also been recorded in southeastern Rewah.

On the south side of this great basin, the Barakars occupy a very large area in the valley of the upper son in Sohagpur, where the river runs from southeast to northwest parallel to the scarp of the Deccan Trap plateau. From the Son valley the Damuda outcrop extends continuously to the east as far as the Jhilmili coalfield, south of the main expanse of Upper Gondwanas.

Along the central section of the northern boundary of this Upper Gondwana exposure is a large outcrop of Lower Gondwanas, while a narrower belt of these older beds partially envelopes the eastern end of the younger exposure in the Tatapani coalfield. On the south the Upper Gondwana tract is bordered by a still larger outcrop of Lower Gondwanas stretching from the Sohagpur coalfield in the west to that of Bisrampur in the east ; the eastern half of this outcrop is pierced by numerous inliers of Archaean gneiss, some of them of considerable size, and the western half has an extremely winding boundary with the gneiss. Several outliers of the Deccan Trap are seen upon the Lower Gondwanas, and trespass here and there across on to the Upper Gondwanas. In a W.S.W. direction, the Gondwana beds of this region disappear irregularly beneath the Deccan Trap, reappear in Jubbulpore, and are probably continuous beneath the Trap with the Satpura basin. A glance at the map will show that, but for the overlying volcanic formation, there would be an almost unbroken belt of Gondwana beds across the Peninsula from near Hoshangabad in the Narbada valley to within forty miles of Cuttack in Orissa, *i.e.*, throughout eight degrees of longitude. A similar continuity no doubt at one time existed from the same western point in Hoshangabad down the Damodar valley to the Raniganj coalfield and beyond a distance of more than nine degrees of longitude.

In the more western coalfields of the Damodar valley, as compared with the eastern, there is a diminution in thickness of the whole Gondwana system, due mainly to the gradual thinning out of all the groups between the Barakar and the coarse, ferruginous sandstones and conglomerates which have been referred to in this work tentatively as the Mahadevas of Upper Gondwana age. This gradual disappearance of the intermediate groups is carried so far that in places the Mahadeva conglomerates rest directly on Barakar rocks. The same relative sequence, a thick mass of sandstones, more or less conglomeratic, resting immediately on Barakars, prevails, so far as is known, in the upper Son valley near Sohagpur and in south Rewah, as well as throughout the Bilaspur, Sambalpur and Talcher coalfields but, as we have seen, it is probable that in the neighbourhood of Sambalpur the lower portion of the higher beds is of Damuda age (Raniganj). A similar sequence occurs in the Godavari valley, where also a conspicuous change in lithological character, accompanied by unconformity, is to be seen between the Barakar beds and the succeeding formation, and where the beds immediately following the Barakars contain Damuda fossils. There is thus a noticeable similarity between the Gondwana succession in the Godavari valley and that in the Mahanadi and Brahmani valleys. In south Rewah also Damuda fossils occur in places at horizons higher than those of the Barakar stage. In the Satpura area the sequence is different. Here a full succession of Lower Gondwana beds is followed by an equally complete succession of Upper Gondwana strata. Although the middle stage of the Damudas resembles lithologically portions of the Upper Gondwanas, there is, as a general rule, a marked contrast between the Lower and Upper divisions of the system. Various portions of this great central tract of Gondwanas may now be briefly reviewed, commencing with the eastern margin ; the areas discussed are as follows :

1. Bisrampur.
2. Lakhanpur.
3. Bansar.
4. Panchbhaini.
5. Damhamunda.
6. Sendurgar.
7. Main Pat.
8. Unimportant outliers.
9. Jhilmili.
10. Kurasia.
11. Koreagarh.
12. Rewah-Sarguja.
13. Johilla.
14. Umaria.
15. Korar.
16. Hasdo-Rehar tract.
17. Singrauli.

Bisrampur.—Between the Tatapani and Korba coalfields is the Bisrampur field of central Sarguja, a large rectangular tract composed for by far the most part of Damuda rocks, about 24 miles across from east to west and 22 miles from north to south, and over 400 square miles in area. On the north it is separated from the broad eastward tongue of Gondwanas which ends in the Tatapani coalfield by a long belt of Archaean gneiss and Dharwars. This northern boundary of the Bisrampur tract is an E.-W. fault throughout, the movement along the fault having brought up the Archaean against the Damuda sediments. Two small patches of Talchirs, however, occur on the north side of this fault and interrupt the adjacency of the Damuda and Archaean outcrops.

The most interesting feature of this field is the southern margin. This is composed of an E.-W. belt of Talchir rocks divided by a small transverse strip of ancient slates and quartzites (? Dharwars). The southern boundary of this Talchir belt is an E.-W. fault which brings up the Archaean, and in one section Damuda rocks; its northern boundary, dividing it from the great square outcrop of Damudas is another fault which in direction is nearer W.N.W.-E.S.E. and therefore not quite parallel to the more southerly fault. Over the middle of this belt of Talchirs lies a small patch of Upper Gondwanas (Mahadevas) which covers not only a small portion of the Talchir rocks across their whole width but also parts of both their northern and southern faulted boundaries; in other words, there are clear indications that faulting preceded the deposition of the Upper Gondwana sediments, and that no recrudescence or repetition of the movement along these dislocations took place after the deposition of the younger beds.

The eastern and western boundaries of the Bisrampur field are for the most part depositional. The strata on the whole are nearly horizontal; they are greatly concealed by alluvium, and sections are seen only in the beds of streams.

The Talchirs, in addition to the two small patches outside the northern fault skirt a considerable portion of the eastern margin of the field, extending in places up the valleys between the ridges of Archaean rocks. To the west and south they are part of a large area outside the field. The original surface on which these beds were deposited around the Bisrampur field appears to have been even more irregular than usual, and in one instance a ridge of Archaean quartzite penetrates the field for six miles with Barakars abutting against it on both sides. The maximum thickness of the Talchirs present is about 200 feet. The boulder bed is well developed at the base and, as usual, occasionally contains boulders brought from a distance; the source of some of the granitic gneiss blocks was evidently not far away.

The Damudas, which belong apparently to the Barakar stage, although occupying so large an area, are very flat-lying and therefore ill-seen, the rock most commonly exposed at the surface being a whitish grit or sandstone occasionally containing pebbles. Coal seams are found in several places, the same seam frequently cropping out in the neighbouring stream sections. None of them is known to be more than six feet thick, but some of the coal is of good quality.

The so-called Mahadevas occur only in the south in the small patch already alluded to, which occupies a small range about six miles long and known as the Pilka hills. Though less ferruginous than elsewhere, they consist of the usual grits and pebble conglomerates with hard quartzose sandstones, and lie unconformably upon the older Gondwana formations. They contain no fossils and, although assigned tentatively to the Mahadevas, are said to be indistinguishable lithologically from the Kamthi beds of the Hingir field in which fossils have been found.

One or two trap dykes have been recorded, but there is no Deccan Trap capping the Upper Gondwanas of the Pilka hills, although the Main Pat (3,500 feet) further south has a summit made up of over 400 feet of the basaltic lavas of this suite.

Lakhanpur.—The southernmost fault of the Bisrampur field, west of the Mahadeva outlier of the Pilka hills, brings the belt of Talchirs which forms the southern margin of this field against a small patch of Barakar rocks adjoining the important village of Lakhanpur. This Lakhanpur field is about nine miles long from north to south, the southern as well as the northern boundary being a fault; the eastern boundary for the most part appears to be a normal one. No beds younger than the Barakars are found within the area, which is much covered by alluvium, the only rocks exposed, as a rule, being in the river sections which are numerous. The field is divided into two, an eastern or Lakhanpur section, and a western or Laingha portion, by the river Rehar (Arand) which flows northwards through it. The whole area has been computed to be about 135 square miles.

Several seams of coal are exposed, the best being one in the Chandnai stream at Katkona, in the eastern section. This seam, which is cut by a fine dolerite dyke just south of the village, is 5½ feet thick where best seen, one half consisting of excellent coal, the other half being of somewhat poorer quality. In the western or Laingha section, several outcrops of coal have been noted, varying in quality from moderate to good.

Trap dykes are common in the field.

Bansar.—Five miles east of Ambikapur is a small area of ten square miles of Barakar rocks known as the Bansar coalfield; it lies within the limits of Sarguja State. A strip of the coal measures stretches westwards through Chendra, as though to join the belt of Talchirs south of Ambikapur, which connects to the west with the Rehar (Arand) river field north of Lakhanpur.[1]

Panchbhaini.—The tiny coalfield of Panchbhaini, including about 4½ square miles of Barakars, is situated in the Paharbula *tappa* of Sarguja. The Talchirs are exposed along the northern boundary, while the southern is a fault. Coal seams, about three feet thick and of good quality, have been recorded in two of the stream courses.

Damhamunda.—The Damhamunda, also 4½ square miles, is another small area of Barakar rocks close to the left bank of the Anjan stream, a tributary of the Hasdo; its thin coal seams are considered to be of no economical importance[2].

Sendurgar.—A more important area of Barakars, some 20 square miles in extent, lies to the west of the Hasdo river in Matin, in the district of Bilaspur, and northwest of the Korba coalfield. Dr. Fox describes the coal measures of this field, which has been named after the village of Sendurgar, as occupying a strip of country about 8 miles long and 2½ miles wide, forming the watershed between the Bamni and Tenti streams.[3] Some coal seams have been proved to occur, and the quality of some of them would appear to justify further exploration.

Main Pat.—Some of the flat-topped hills in eastern Sarguja are capped by plateaux of sandstone, belonging perhaps to the Upper Gondwana division. In some instances, as on Main Pat, a high plateau north of Udaipur, this sandstone is covered by basaltic trap of the Deccan trap suite which in its turn is capped by laterite. On Main Pat the sandstone is about 300 feet thick; to the north of the plateau it rests on Talchir beds, elsewhere on Archæan rocks with Talchirs appearing between here and there. The Talchirs north of the plateau extend in the form of a belt from two to four miles broad, for sixteen miles northwards to Bisrampur, where they dip under Barakars. Besides the outlier of Mahadeva sandstone resting on the Talchir belt of Bisrampur, another caps a hill of Archæan rocks close by.

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[1] C. S. Fox. *Mem.* LIX, 216-217 (1934).
[2] C. S. Fox. *Mem.* LIX, 221 (1934).
[3] *Ibid.* 221.

Unimportant Outliers.—Small unimportant patches of Talchir beds are scattered throughout many of the valleys of eastern Sarguja and neighbouring parts; among them are the following: Murmuri; Bachrajkuar; two miles east of Tulbul; Lakandih; northeast of Bhandar; Jajgi Hill; Dhitori Hill; and Chibri.

Jhilmili.—Along the southern margin of the great Rewah-Sohagpur basin of Gondwana beds which terminates eastwards in the Tatapani coalfield are several coal bearing fields to which individual names have been given for purposes of convenience. The Jhilmili area, which lies W.S.W. of Tatapani and due west of the northern portion of the Bisrampur field from which it is divided by an embayment of gneiss, possesses some individuality owing to its almost complete separation from the main south Rewah and Sohagpur basin by a southwardly-throwing fault. With an area of about 35 square miles and an extreme length of 25 miles, this small tract of Barakar rocks lies to the south of the E.N.E.-W.S.W. fault just mentioned, but the name, Jhilmili, has recently been extended to country north of the fault, including a narrow band of both Barakars and Talchirs which wind up the Mahan valley in the northeast. South of the fault, where they are cut off in the usual manner, the Barakars dip northwards. To the south is a great expanse of Talchirs with gneissic inliers, some of them of considerable size, the Barakars resting usually on Talchirs but occasionally on the gneiss.

Perhaps the most interesting feature of the Talchirs of this field is the abundant occurrence, amongst the boulders of the boulder bed, of masses of the characteristic compact Vindhyan sandstone or semi-quartzite. The nearest source of this rock is the Kaimur scarp beyond the Son river, 70 or 80 miles distant to the north. Similar rocks occur also to the south in Chhattisgarh and Sambalpur but the distance is even greater. As Medlicott and Blanford remark, it is improbable that the boundary of the Vindhyan outcrop in this instance was very much nearer in Talchir days, because so large a portion of the intervening area is occupied by Gondwana formations, and these nowhere rest upon Vindhyan rocks within the topographical limits mentioned.[1]

Dr. Coulson has recognised four coal horizons in the Barakars of this field and some of the coal is of excellent quality, though no seam appears to be much more than six feet in thickness.

Some trap dykes are met with in this field.

To the north of the E.N.E.-W.S.W. fault, which appears to fade out westwards, is an upthrow belt made up first of all by gneiss, Bijawar and Talchir beds followed further north by Barakars carrying outliers of Deccan Trap. This belt, the Barakars of which are an integral part of the main Rewah-Sohagpur Barakar outcrop, is characterised by dolerite sills and dykes believed to be of Deccan Trap age and is cut off from the immense exposure of Upper Gondwana beds to the north by an E.-W. fault with a throw to the north.

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[1] Man., 1st Edit., pt. 1, p 205 (1876).

Kurasia.—To the W.S.W. of the Jhilmili field is another even better defined tract of Barakars, completely isolated from the main exposure to the north by a broad belt of trap-covered Talchirs pierced here and there by gneissic inliers. This Barakar area, named after Kurasia, the only village it carries, covers 48 square miles of hilly country. The Barakars lie almost horizontally on the Talchirs, and some of the coal therein is of excellent quality. On the high ground in the eastern parts of the area are two tiny outliers of supra-Barakar Gondwana rocks.

Koreagarh.—A few miles southeast of the Kurasia area is the still smaller field of Koreagarh. Tiny as this basin is, it includes two little outliers of supra-Barakar rocks (?Mahadevas), one of them capping the hill which has given its name to the field. The six square miles of Barakars, which are entirely surrounded by Talchirs, the boundary being one of deposition, contain one or two thin seams of coal. A dyke of dolerite crosses the Barakars.

Above the Damudas come beds which in general have been referred to the Upper Gondwana division, but it is not impossible that they include at their base horizons of Panchet age, such as the Parsora beds. The succession includes typical Mahadeva sandstone, pebbly, current-bedded, and containing thin bands of hard ferruginous shale of a brick-red or dark brown colour. This type of bed has been traced across the whole region, and it is mainly on the strength of this evidence that the Mahadevas of the type area in the Satpura hills have been correlated with their probable representatives in the Damodar valley. In south Rewah, as elsewhere, the Upper Gondwanas are probably unconformable to the underlying formations.

The highest group of the Gondwanas present in this tract is the Jabalpur series and is known only to the westward in Sohagpur and southwest Rewah. It consists of a great thickness of coarse felspathic sandstone, forming, amongst other hills, that on which stands the fort of Bandogarh, and resting upon lavender-grey and white shales ; these beds are also well seen at Bansa, a few miles west of Bandogarh. With the shales, which have yielded abundantly the characteristic Jabalpur plant remains, there is associated locally a band consisting of fine layers of jet. A common feature of the Jabalpur beds in this area is local induration, the sandstones attaining the texture of a quartzite, and the shales becoming porcellanic.

Basalt dykes and sills of Deccan Trap age occur throughout south Rewah and Sohagpur, and some of the hills of sandstone in Sarguja are capped with the same trap. There is little doubt that the time limits between which faulting occurred in this and other Gondwana areas were very wide. In the Bisrampur neighbourhood, there is clear evidence that such dislocation preceded the deposition of the Upper Gondwanas. In some cases there is reason to suppose that the accumulation of the Upper Gondwana sediments was accompanied by contemporaneous faulting ; the association of intrusions of Deccan Trap with lines of disturbance supports the view that the faulting in these cases preceded or accompanied the trap intrusions. In a few instances, especially where the fault-lines are characterised by hot springs, dislocation appears to have taken place later—perhaps considerably later—than the Deccan Trap period.

The main area of the coal-bearing rocks of south Rewah, with an average width of about 26 miles and covering some 1,600 square miles, was originally given the name of the Sohagpur coalfield, but this tract has since been split up into three more convenient units—the Sohagpur field proper (1,200 sq. miles), the Jhagrakhand field (61 sq. miles) and the Sanhat field (330 sq. miles). Along the north west and south of the Sohagpur area, the Barakars are covered by the so called supra-Barakars which have not yet been clearly separated from the Barakars but which include beds with fossil plants indicating a Raniganj age in spite of their lithological resemblances to Upper Gondwana strata ; an outlier of these supra-Barakars occurs on Mahora Hill below a capping of Deccan Trap basalt, originally part of a sill. These beds form what is known locally as the Pali or Pali-Daigaon stage. Southwards and eastwards the coal measures are seen to overlie the Talchirs, which in turn rest on Archæan rocks. In the more southerly part of this area, south of Bamhani, is a small inlier of Talchirs brought up by and on the south side of a short fault. The area as a whole is characterised by the presence of large sills and dykes of dolerite which, although very irregular in outcrop, have an approximate E.-W. trend.

The Sohagpur field, in its restricted sense, embraces the northern and western parts of the Lower Gondwana outcrop. Several outcrops of coal have been recorded in this large field in spite of the flatness of the beds. The main seam in some places swells to 27 feet. For a short distance in the southwest, the coal measures are discordantly overlain by Lametas which lie below the basaltic flows of the Deccan Trap.

The southeastern portion of the main area of coal-bearing rocks is known as the Jhagrakhand coalfield. To the east and south, the Talchirs make their appearances from beneath the coal measures, the general dip being northwestward at low angles. Three coal horizons are known to occur, the lowest comprising two seams of excellent quality ; none of the seams known is over 7½ feet thick.[1] No supra-Barakar rocks have been recognised in this area, across parts of which extend several important dolerite dykes.

The eastern portion of the main coal-measure outcrop is the Sanhat field which lies in Korea State, and is joined to the Jhilmili basin on the E.S.E.by a narrow connecting bridge of Barakars. The Barakar rocks, of which the field consists, are followed to the north by the main outcrop of what are believed to be Upper Gondwanas. Along the southern margin is the large expanse of Talchirs appearing from beneath the coal measures and diversified with inliers of Archæan gneiss, and E.-W. dykes of trap ; in this expanse of Talchirs occur the small isolated coalfields of Kurasia and Koreagarh. The eastern and southern margins of the Barakars are traversed by a belt of dolerite intrusions of the Deccan Trap. Three coal horizons have been recognised in the Barakar beds but the seams are not thick and most of the coal has a somewhat high ash percentage.

Johilla.—A few miles west of the main tract of Barakars in Sohagpur and separated therefrom by a short expanse of Upper Gondwanas is a small area of gneiss and Lower Gondwanas on the Johilla river, a tributary of the Son, in the neighbourhood of Pali. A thickness of about 3,000 feet of Talchir and Barakar beds is exposed in two areas separated from each other by the inlier of gneiss. There are thus two small coalfields, one on the northern and the other on the south-eastern side of the gneiss. North of the gneiss is a belt of Talchirs followed by about 11½ square miles of Barakars with at least two valuable coal seams, one of them 17 feet thick ; these beds are overlain in their turn by the Pali-Daigaon beds of Raniganj age which are followed by the so called Mahadevas. All these beds show a gentle and more or less steady dip towards the north. Plant fossils found below one of the seams in the Johilla river include two species of *Gangamopteris* which suggest a Karharbari age. Allowing for a 25-per cent. loss in working

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[1] C. S. Fox. *Mem.* LIX, 206 (1934).

Dr. Fox estimates the reserves within a depth of 500 feet in this northern section to be 30 million tons.

In the tiny southeastern area, the Talchirs are again seen lying upon the southeastern flank of the gneissic inlier, and followed by some 3¼ square miles of Barakars. The dip is in general eastwards, and the Raniganj beds which follow the Barakars evidently overlap the latter on to the Talchirs, and appear to be faulted against the gneiss along a short N.E.-S.W. boundary. No promising coal seams have so far been detected in this area.

Umaria.—Northwest of the Johilla river fields is another but larger inlying strip of gneiss, extending roughly N. E.-S. W., and carrying on its northeastern end two small separate coalfields, the Umaria field to the south and the Korar field to the north. The Umaria field lies in an angular embayment of the gneissic outcrop caused by a N.E.-S.W. fault, and is separated from one tongue of the gneiss by this fault. Talchirs occur to the southwest of the coal-bearing rocks and in this direction lie upon the gneiss. The next younger beds are the marine Lower Permian ("Permo-Carboniferous"), found lying with a slight break upon the Talchirs in the railway cutting west of Umaria station. These are succeeded with no apparent unconformity by the coal-bearing Barakars and appear to correspond more or less to the Karharbari beds of Giridih. The coal-bearing rocks are covered by the supra-Barakars which are possibly of Ranigan age, and these by the Upper Gondwana deposits. Mr. K. P. Sinor states that there are six coal seams, four of which are workable.[1]

Korar.—The Korar field is found on the northeastern end of the tongue of gneiss mentioned in the preceding paragraph, and lies to the north of the Umaria exposures. As in the latter, the gneiss is overlain to the northeast by a belt of Talchir sediments, and these are followed in the same direction by Barakars and the latter possibly by Raniganj beds; Upper Gondwanas complete the sequence. A thin fringe of the Talchirs also extends down the northwestern margin of the gneiss for about six miles, and there is a small inlier within the coal-measure outcrop. The southeastern boundary of this field is a continuation of the same fault which forms the northwestern boundary of the Umaria field. Half-a-dozen outcrops of coal and carbonaceous shale have been reported to occur in this area. A large sheet of trap extends nearly the entire length of the field.[2]

Hasdo-Rehar Tract.—To the north, the Korba field is incompletely separated by a large inlier of gneiss from an extensive tract of coal measures stretching from the upper waters of the Rehar (Arand) in the Main Pat area of Sarguja westwards beyond the Hasdo to the neighbourhood of Korbi in the Matin *zamindari* of north Bilaspur. From the Chitai stream in Paharbula (Sarguja) to Kendai in the Uprora *zamindari* of Bilaspur it is some 15 miles across. The Damudas of the eastern part of this tract are continuous with those of the Korba-Dharmjaygarh area beneath the exposure of Upper Gondwanas. In the opinion of Dr. Fox, the coal measures of this tract must cover nearly 400 square miles in the *tappas* of Rampur and Paharbula in Sarguja State and in the adjoining *zamindari* of Uprora and Matin in the district of Bilaspur. The Sendurgarh coalfield lies beyond the western or Matin end of the field, and the outliers of Damhamunda and Panchdhaini are situated between it and the Lakhanpur coalfield to the north. Northwest of the tract is the large expanse of Talchir beds which skirts the southern border of the

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[1] "Mineral Resources of Rewa State", p. 23 (1923).

[2] T. W. H. Hughes, *Mem.* XXI, pt. 3, 26 (1885 reprint (1923).

Sohagpur-Korea coal-measure exposure. A tongue of these rocks also separates the Barakar outcrop of the Matin or western end of the tract under review from that of the Korba field. Throughout the area many coal outcrops have been noted : none of the seams is of any considerable thickness but some of the coal appears to be of good quality.

Singrauli Coalfield.—On the northern margin of the Sohagpur-Rewah tract is the Singrauli area, which stretches from the western borders of the Mirzapur district through the Singrauli *ilaqa* of eastern Rewah to the Gopat river and beyond ; the coal-bearing Damudas here cover an area of about 900 square miles, and consist predominantly of coarse felspathic sandstones, shales being less abundant. These beds belong apparently to the Barakar stage, and in one place include a conglomerate containing rolled pebbles derived from the Talchirs. The rocks all dip at low angles, or are nearly horizontal. Several coal seams have been noted by Mr. K. P. Sinor, the most important being those near Naunagar, Koelkat, Amlei and Ujehni ; other known areas are Kota and Parari (?Pudri). Although the seams, as a rule, are thin, that near Naunagar is upwards of 18 feet in thickness and of good quality in parts ; the six-foot Parari seam is also promising.[1] Further west, on the Gopat river, there is a great thickness of coarse felspathic sandstones with occasional flaggy beds, shales and seams of inferior coal ; associated with a sandstone below these beds at Keryli, however, is a seam five or six feet thick, which is said to be of excellent quality. It has been suggested that the uppermost beds of the Gopat river section may represent the Raniganj stage. A little to the west of the Gopat, the Lower Gondwanas are covered by the beds of the Upper division.

VI.—SATPURA REGION.

The Gondwana rocks of the Satpura region occupy the hilly country of southern Hoshangabad, northern Chhindwara and northeast Betul, lying to the south of the Narbada plains. From the most westerly end of the Sohagpur region of Lower Gondwanas, which is the Umaria coalfield, the nearest point of the main Satpura outcrop of these rocks is over 140 miles distant in a W.S.W. direction. This Satpura tract of coal-bearing rocks is flanked on the north by a broad belt of Upper Gondwana strata, which extends much further to the E.N.E. than the Lower division rocks, tapering out along the northern slopes of the Mahadeo hills through southern Narsinghpur where it comes to an end ; there are, however, narrow strips and small outlying patches of these rocks in Jubbulpore which form links with the Upper Gondwanas of Sohagpur. The area between the two regions of Gondwana rocks is covered by the basaltic lava flows of the Deccan Trap which evidently at one time extended much further to the east over a large portion of the Sohagpur-Rewah area. Along the northern edge of the Upper Gondwana outcrop of the Satpura region are several small isolated basins of Lower Gondwana beds, all save one consisting only of Talchir rocks.

Though probably occupying basin-shaped depressions in the Archæan, the Gondwana formations of the Satpura hills form part of a vast inlier exposed by denudation in the bedded volcanic rocks of the Deccan Trap. East of Hoshangabad Gondwana rocks are nowhere known north of a line drawn along the northern base of the hill range ; further west, however, a few representatives of the highest Gondwana group of the area have been noted north of the Narbada though still in the valley of this river.

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[1] *Mem.* LIX, 181 (1931).

The strip of Gondwanas adjoining the town of Jubbulpore is composed entirely of rocks of the Upper division and extends for some twenty-five miles, with one interruption near Lameta Ghat, along the edge of the traps which cover all the country to the southward. This outcrop, however, is obviously continuous E.N.E.-wards beneath alluvial deposits and the Deccan Trap with the Gondwanas of Sohagpur. The beds exposed consist chiefly of the usual lavender-grey and white clays, and earthy sandstones which are generally soft but occasionally much indurated. They appear to rest in places on the Archæan, but elsewhere to be faulted against them. Some coal is found in the Jabalpur series at Lameta Ghat on the Narbada ; the seam is irregular and of small thickness, and the coal is jet-like. Coal has also been found in a well in Jubbulpore itself, and in several exposures along the Mahanadi to the northeast of the town, in the Sihora *tahsil*.

The Upper Gondwana tract east and southeast of Narsinghpur is somewhat broader than that near Jubbulpore since it extends in some places for five or six miles up the valleys of the Umar, Sher and other rivers, which cut deep gorges out of the overlying volcanic rocks. The beds exposed consist of conglomerates at the base, succeeded by soft shales, some of them carbonaceous and containing jet-like coal in bands which are in places nearly two feet in thickness but generally much thinner. Seams have been noted near Sihora on the Sher river as well as at the junction of the Sakkur and Hard rivers. Resting on the shales are coarse sandstones and grits, which are probably the equivalents of the sandstone beds of Bandogarh in Rewah.

Disregarding one or two short interruptions, the length of the Satpura tract proper, from the eastern limit of the Narsinghpur district westwards to a point due south of Seoni Malwa, is just under 140 miles, while its average breadth is about 40 miles from north to south. The area of Gondwana rocks actually exposed is less than 2,000 square miles. The southeastern portion of the region is drained by the Kanhan and Pench, tributaries of the Wainganga which joins the Godavari ; the remaining and major portion belongs to the Narbada drainage.

As in the Rewah region, there is a prevalent dip of the rocks of the Satpura Gondwanas towards the north, the lowest beds being exposed chiefly near the southern boundary. On the east the tract is overlain by Deccan Trap, on the west by Deccan Trap and the Narbada alluvium.

According to Dr. Fox, the northern boundary of the Satpura Gondwanas is characterised by three lines of parallel faults, the newest extending in the Narbada plains along the base of the hills with a downthrow to the north. The oldest fault comes next and lies a short distance further south, within the hills ; it has a downthrow to the south and appears to have been the northerly limit of the Lower Gondwanas. Between these two faults the Archaean rocks often show as inliers. The third and most southerly fault, with a down throw to the south, is seen south of Mohpani and is thought to have been largely contemporaneous with the deposition of the Upper Gondwana sediments. Between this fault and the middle one, the Talchirs and Barakars appear in places, but Upper Gondwana strata have been deposited across both lines of the two older and inner faults. These Upper Gondwanas, as well as the Deccan Trap lavas, extend out under the alluvium of the Narbada and have been dropped by the latest and outermost fault.[1] It is clear, therefore, that dislocation along the two inner and more southerly faults took place before the Upper Gondwana period.

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[1] *Mem.* LIX, 244-245 (1934).

The southern boundary in the Chhindwara district is faulted. In the Betul area further west it is irregular, possibly as a result of excessive erosion in the Tawa valley. The faulting in the south shows no evidence of having taken place at different times, though it may have done so along the same plane of dislocation, The latest displacements, in any case, have affected the Deccan Trap.

The northern portion of the region consists chiefly of great sandstone plateaux, built up of the subdivisions of the Mahadeva series. East and west, these plateaux terminate to the northward in scarps from 800 to 1,000 feet high, overlooking the alluvial plain of the Narbada. The central portion of the region is composed of the Mahadeo or Pachmarhi hills, rising to an elevation of 4,380 feet above sea-level, and consisting of the typical Mahadeva (Pachmarhi) sandstone. The southern portion is less hilly, being made up of Lower Gondwana rocks. The latter, nevertheless, appear at a considerable altitude to the southeast at the top of the watershed between the Narbada and Godavari drainage, as well as in the high upper valleys of the Pench and Kanhan ; to the west, they occupy the much lower ground of the upper Tawa valley.

The following are the groups exposed in the Satpura region :

Jabalpur series :

Mahadeva series	Bagra stage ; Denwa stage ; Pachmarhi stage.
Damuda series	Bijori stage ; Motur stage ; Barakar stage.

Talchir series.

Very little reliable information is available regarding the thicknesses of the groups, some of which swell rapidly from a minimum figure to a maximum many times greater. Any estimate is made still more difficult by strike faulting. The Talchir series is said to be 1,000 feet thick, and a doubtful figure of 500 feet has been suggested for the Barakar. The Motur stage may be between 3,900 and 5,700 feet southwest of Pachmarhi, and a thickness of 6,000 feet has been suggested as a maximum, while the Bijori, which is only 600-800 feet thick to the southwest of Pachmarhi, may rise elsewhere to a maximum of between 3,000 and 4,000 feet. At a rough estimate, and assuming a uniform dip of five or six degrees, the total thickness of the Lower Gondwanas immediately south of the Pachmarhi plateau must be at least 8,000 feet. The thickness of the Mahadeva series was formerly assessed at 10,000 feet, but the maximum figure is probably nearer 3,000 feet, the beds in places dwindling to 500 feet. As already explained, the so-called stages are little more than facietal variations. A thickness of 1,000 feet has been suggested for the Jabalpur series.

The Talchir beds, consisting of the usual sandstones and clays, with boulders, occur continuously along the southern boundary of the tract. In some places, as at the head of the Tawa valley, south of Motur, they are very thick and are particularly well exposed on the hill-sides. They are also found in several places along the northern boundary, always greatly disturbed and often faulted. In this position they are seen in the following places, from east to west : Nibhora, west of the Hard river, where the Bagra conglomerates rest upon them ; Mohpani, on the Sitariva, where they are associated with Barakars ; in the gorge of the Anjan as its junction with the Pathapani, above Fatehpur (two separate small inliers in the Denwa beds) ; a minute inlier, south and a little east of Pindrai ; three comparatively large outcrops, southeast, south and southwest of Piparia Railway Station, the middle one traversed by the Piparia-Pachmarhi road, all overlain by Denwa beds or trap intrusions. Except at Mohpani, the overlying sedimentary rocks in all cases belong to high Mahadeva horizons, and are of course quite unconformable ; in the three larger outcrops south of Piparia, the junction between the Talchirs and Denwas has been for the most part intruded by sills of the Deccan Trap. The western half of the northern boundary appears to be devoid of these Talchir exposures. The Talchirs of this region are generally unfossiliferous, but in the Betul area plant remains have been found in beds assigned to the Talchir series. Dykes of the Deccan traps are numerous in the Talchirs, and there are two or three inliers of Archæan.

The Barakar is the only group in which useful coal has hitherto been found. Its sediments are characterised almost everywhere by poorly preserved plant remains, chiefly impressions of leaves or of *Vertebraria*. Like the Talchir, this group is chiefly exposed near the southern boundary. In the west, it occupies a considerable area in the upper Tawa valley in northern Betul, where the plane of division between the Talchirs and Barakars is less marked than usual and there is an apparent passage from one into the other. Towards the east, the Barakars are well exposed in the Kanhan and Pench valleys of central Chhindwara. There is little doubt that these beds are continuous northwards with the Barakars of Mohpani beneath all the younger strata which lie upon them, but, as Dr. Fox remarks, by far the larger part of these concealed Barakars must be buried so deeply as to be beyond the reach of exploitation. In the extreme southwestern portion of the Satpura region (Sonada coalfield) as well as in the Mohpani area, certain horizons of the coal measures containing *Gangamopteris cyclopteroides* are thought by some to represent the Karharbari " stage ".

The Barakar stage presents the usual appearance and consists of brown and grey felspathic sandstones, flaggy beds, shale and coal. In the Sonada area exposures of poor coal are to be seen, but no workable seams have so far been proved ; in this small tract thin coaly layers occur in typical Talchir rocks with leaf impressions characteristic of the topmost Talchirs in certain parts of the Karanpura coalfield. The beds here dip northwards at about eight degrees. Further to the east, the Barakars north of Shahpur dip northwards towards the Tawa river, where they appear to be cut off by a northward-throwing fault ; to the south also these beds are said to be separated from the Talchirs by an E.-W. fault. Coal seams were actually worked for a short time in this part of the area, but they are thin and have probably been affected by dolerite dykes. From this tract of Barakars another to the east of Shahpur has been shifted laterally by a N.E.-S.W. fault ; it also contains coal seams of doubtful value. Southwest of the latter tract is a tiny area of Barakars crossed by the Tawa at Dulhara and covering about 1½ square miles ; it is largely bounded by faults and is known to contain a few coal seams. Connected with this small field by a narrow strip of Barakars is a broad but irregular tract of the same rocks, traversed twice by the Tawa river and spoken of as the Tawa field. Seams of coal have been recorded, the most promising being those at the southwestern end, where, however, the field is traversed by several dolerite dykes and the strata are disturbed along their eastern margins ; southwards, the beds are said to be faulted against the Talchirs and the gneiss. Further to the east is the Kanhan coalfield connected with the Tawa field by a thin bridge of Barakars. In the

Kanhan area the Barakars trend due E.-W., dipping gently to the northward and having an outcrop averaging over a mile in width ; to the south they are faulted against the Talchirs and are themselves traversed by at least two strike faults. The whole tract is sliced by parallel faults, but three or four seams of coal of workable thickness are present, and the topmost seam appears to be both thick and of good quality ; some of the coal is probably of coking propensity. Southeast of Jamai, the Kanhan field ends and the Hingladevi field begins. Here the Barakar sandstones are in force along the ridge which extends east and west through the village of Kamkunda ; the western half of the Barakar outcrop is faulted against the Talchirs to the south, while the eastern half is faulted along another line against an outlier of Deccan Trap. A fault trending E.-W. follows also the north side of the ridge bringing in the Motur beds ; this boundary is also complicated by an oblique dolerite dyke.

East of, in a line with, and almost adjoining the Hingladevi field, are the Pench Valley coalfields, situated northwest of Chhindwara in the drainage of the Pench river. A continuous strip of Barakars trends eastwards from Barkui to the Pench river near Setia, while there are several disconnected inliers beneath the Deccan Trap further east and one inlier to the south. On the south side of the main Barakar outcrop a small tract of Talchirs, including the boulder bed, is exposed and is overlain with no discordance by the younger formation. The thickness of the latter here is estimated to be between 350 and 400 feet, and leaf impressions of typical Damuda plants are frequently to be found therein. Several seams of coal are known, and four of them may prove to be workable. The best seam, which is in process of being exploited, occurs some 120-150 feet below the base of the Motur beds, and varies from 5 to 12 feet in thickness. The largest inlier is that of Sirgora, beneath the Deccan Trap but separated therefrom by a thick bed of Infra-trappean conglomerates.

There is only one locality along the northern boundary of the Satpura tract in which the Barakars make their appearance ; this is the Mohpani coalfield on the Sitarewa river, where the beds are much disturbed and tilted. The area is faulted and has the general structure of an anticline with an axis pitching eastwards, since the Barakar outcrop can be followed from north to south round a core of Talchirs just east of the river. Northwards, in the neighbourhood of the Sitarewa the Barakars are succeeded by a narrow outcrop of the Mahadevas in which at least one dolerite dyke can be seen following the strike of the beds. The dip of the Talchirs, Barakars and Mahadevas in this northern limb is almost vertical. Beyond the strip of Mahadevas to the north is the Narbada alluvium. Eastwards this Mahadeva strip tails out beneath the alluvium, the latter overlapping on to the Barakars, a long strip-like prolongation of which branches off eastwards from the main exposure for a mile or more along the edge of the alluvium. Along the northern limb of the anticline all the Gondwana rocks are excessively crushed and probably close to the northern limits of the Satpura tract as a whole. No older rocks than the Talchirs are seen in this area, but both to the east and west Bijawar rocks come to the surface along the edge of the alluvium. Several borings put down in the alluvium to the north reached depths up to 500 feet without attaining any country rock.

In the southern limb of the anticline, the dip is lower but still somewhat steep (up to 22° in the Barakars), and there is much less crushing. The Barakars appear to follow the Talchirs conformably, and are reminiscent of the Karharbari stage.

Coal, some of it of excellent quality, was worked for many years in the Mohpani area and more recently at Gotitoria, two miles further west, but the collieries were dismantled in 1927 ; in the former area four seams were proved, one of them 18 feet and another 14 feet in thickness. Coal mining has been restricted to the southern limb of the anticline where the beds are less inclined. Irregular faulting, however, has broken up the Barakars into blocks. To the south and east the Barakars are overlain by the Bagra conglomerates with a great time-break if not with an angular unconformity ; south of the old colliery the Barakars are said to be faulted against the Bagras.

In contrast to the northern parts of the Satpura tract, the coal-bearing Barakars of the coalfields in the south-Shahpur, Tawa, Kanhan, Pench Valley and others—are succeeded without discordance, except in the Pench valley where a slight unconformity can be detected, by the beds of the Motur stage which, although resembling the Panchets lithologically, are referred to the middle Damudas from the evidence of extremely scanty fossils. The village of Motur, after which the stage has been named, stands actually upon the edge of a tongue of Deccan Trap which stretches westwards over the upper Pench valley. The Bijoris, which follow the Moturs, have a more Damuda-like facies and are referred to the upper or Raniganj stage of that series ; thin seams of poor coal and carbonaceous shales have been observed in them. Outcrops of this stage extend northwards up to the cliffs of the Pachmarhi hills, though one or two small faulted inliers are recorded on the north side of the range. The Bijoris are well exposed in the upper Denwa valley. The Moturs and Bijoris occupy a large area, some 50 miles in length and 20 miles in maximum breadth, covering the extensive flats and hills drained by the Tawa and its tributaries, including the Denwa, south of the Pachmarhi range.

The inter-relationships of the three Mahadeva subdivisions have already been discussed (page 967). The thick, massive and nearly horizontal sandstones and grits of the Pachmarhi group are well seen along the scarp forming the southern face of the Pachmarhi range, unconformably overlying the Bijoris. The Pachmarhi outcrop has been traced for some sixty miles from east to west. Where widest, it is 12 miles across, but this is due to the fact that the group here attains a maximum thickness and gradually thins out both to the east and to the west. How far this thinning-out is due to replacement by beds having the lithological characters of the middle Mahadeva group, and to what extent it is the result of a difference in the amount of sediment deposited in neighbouring areas, is less clear ; to the eastward the former certainly appears to be the more likely explanation, for in this direction the Pachmarhi facies entirely disappears and is apparently replaced by Denwa sediments.

The Denwa group appears to be in many respects a repetition at a much higher horizon of the conditions which prevailed during the deposition of the Motur sediments. It is chiefly developed north of the Pachmarhi hills ; to the west it is overlapped, but it can be traced for a long distance to the east, though its appearance here is less typical than it is in the Denwa valley.

The Bagra group, an essentially conglomeratic one, can be recognised throughout the greater part of the northern margin of the Satpura tract. Small patches of it can be recognised as far east as the country due south of Narsinghpur.

The Jabalpur group is developed chiefly in the northeastern portion of the Satpura tract. It forms nearly the whole of the sandstone area north of the tongue of Deccan Trap and east of the watershed between the Dudhi and Sitarewa rivers. A tiny outlier caps a hill, six or seven miles west of the Dudhi, and further westwards, four or five equally small outliers are seen at various places between this and the Hoshangabad-Itarsi railway line and road, lying on the Bagra beds along or near the northern edge of the Gondwana tract. A few miles west of the railway line and road are two more outliers, one of which occupies a small stream course below the Khatama caves and is characterised by some layers of coal. On the other side of the Hather stream is a much larger exposure of the Jabalpur, situated to the southeast of Seoni Malwa, traversed by the Moran river and largely covered by Deccan Trap ; here also coal seams occur, in the river near Lokartalai at the extreme western point of the Satpura Gondwana tract.

Trap dykes abound throughout the whole Satpura area, many of them being of large size. In many places the intrusions have spread horizontally between the beds to form irregular sills ; this is chiefly the case amongst the beds of the Upper Gondwana division, and especially in the Jabalpur series. The large mass of dolerite, for example, at Gotitoria Hill in the Mohpani coalfield is believed to be a laccolite exposed by denudation.

VII.—NARBADA WEST OF HOSHANGABAD.

For some distance west of Lokartalai, where the Gondwana rocks of the Satpura tract disappear beneath the Deccan traps, there is, along the southern edge of the Narbada valley at the base of the hills, a line of disturbance in southwestward continuation of that seen along the northern boundary of the Satpura tract. Along this line of fracture, the volcanic beds are turned up sharply and dip to the south. From beneath them, here and there, small outcrops of sandstone appear, belonging by their characters evidently to the Bagra group of the Mahadevas. The best exposure is in the Ganjal stream, six or seven miles west of Lokartalai. Sandstones can be traced at intervals for another four miles and visible evidence of the line of disturbance continues for twenty-five miles. About 30-35 miles from Lokartalai, close to Hindia on the Narbada, are the coarse conglomerates which near Barwai, fifty miles further on, are found beneath the Cretaceous oyster beds of the Bagh series ; these conglomerates and the Nimar Sandstone of the lower Narbada valley have much in common with Upper Gondwana sediments, and there are no strong reasons for not regarding them as such ; they will be described under the heading of the Bagh Beds (Cretaceous), and are referred to again at the end of this chapter.

VIII.—UPPER TAPTI REGION.

South of the Gondwanas of the Satpura region is a belt of Archæan gneiss and Dharwar rocks which, like the aforesaid Gondwana tract, has been exposed by the denudation of the overlying Deccan Trap. This short belt of the ancient floor-rocks of the Gondwana sediments is girdled on the west, south and east by the outcrop of the Deccan Trap except where the river Kanhan has cut down through the traps to the gneisses below in the southeastern corner. The western margin of this Archæan tract, however, is not everywhere in contact with the overlying trap but is, throughout most of this portion of its boundary, separated therefrom by a narrow tortuous fringe of sediments which have been assigned doubtfully to the Lower Gondwana. This fringe of sediments, situated to the west and northwest of the town of Betul, at an elevation of 1,500-2,000 feet above the sea, on the plateau which forms the watershed of the Satpura range, lies on the headwaters of the Tapti entirely outside the Narbada valley. How far these sediments stretch under the Trap westwards and whether they were ever continuous with the coalfields that trend from Shahpur to the Pench valley along the southern margin of the Satpura tract, is not known.

The beds, which comprise a conglomerate, sometimes cherty, and occasional sandstones and clays, vary greatly in thickness; throughout a considerable distance they appear not to exceed 100 feet, and are often thinner. The conglomerate is described as exactly similar to one met with in the Dhar Forest and referred to the Lametas[1], while the soft argillaceous sandstones, with harder bands, and occasional red shales or clays, seen near the villages of Alampur, Khettapani and Khamapur, show considerable resemblances to some of the Mahadeva rocks. One portion of the rocks in question is horizontal, while another is inclined, sometimes at steep angles apparently as the result of faulting. In spite of certain differences, Mr. H. Walker regards the two portions as of the same age, and is inclined to refer all the sediments to the Talchir series.[2] No fossils have been found in the beds.

IX.—GODAVARI REGION.

The name, Godavari, is restricted above Sironcha to the southern affluent of the river, but the northern branch, known as the Pranhita and formed by the union of the Penganga, Wardha and Wainganga, is equal in size to the main stream. The great Godavari belt of Gondwana rocks covers an area probably greater than that observed in the drainage of any other Indian river. It extends from a point forty miles south of the town of Nagpur, through the plains of the Pranhita and the Godavari, to the coast alluvium in the neighbourhood of Ellore and Rajahmundry, but some additional detached outcrops northwest and west of Nagpur are probably integral parts of the belt.

Under this heading will be considered the following:

1. Inliers near Ellichpur;
2. Inliers west and northwest of Nagpur;
3. Kamthi area;
4. Bandar coalfield;
5. Outliers near Khair and Arjuna, south of Wun;
6. Wardha-Pranhita-Godavari basin.
    - (a) Wardha coalfield;
    - (b) Central portion of the Godavari valley, including the outliers northeast and east of Pakhal Tank, and the Singareni coalfield;
    - (c) Southeast portion of the Godavari valley, to the neighbourhood of Ellore and Rajahmundry.

Inliers near Ellichpur.—Along the southern scarp of the great spur which, branching off from the Satpura range near Betul and extending from east to west between the valley of the Tapti and that of its large affluent, the Purna, is known by the name of the Gawilgarh hills, there are exposed beneath the Deccan Trap lavas and Infra-trappean beds along the northern or upthrow side of a well known E.N.E.-W.S.W. fault certain sediments assigned tentatively to the Kamthi (? Mahadeva). These inliers, which lie but thirty miles south of the doubtful conglomerates, sandstones and clays in the Tapti valley west of Betul, extend for a considerable distance—in one case for several miles—along the foot of the Gawilgarh scarp. The most westerly of these inliers occurs about eight miles north of Ellichpur, and continues east and west for a distance of six or seven miles. For sixteen miles to the east, no sedimentary rock is seen *in situ*, though at one spot, three miles west of Narha, the occurrence of some blocks of sandstone may indicate the presence of a small outcrop. At Narha, about 22 miles east of Ellichpur, the sandstones reappear north of the fault and extend for fifteen miles; they, then, disappear again, but two small inliers, each about a mile long, occur at short intervals just beyond.

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[1] W. T. Blanford. *Mem.* VI, pt.3, 53 (1869).

[2] *Gen. Rep. Rec.* XLVII, 37 (1916).

In these inliers infra-trappean Lameta beds occur immediately beneath the basaltic traps, and are succeeded in descending order by about 500 feet of strata comprising felspathic sandstones, white and brown conglomeratic beds, occasional ferruginous beds, and thin layers of white and purple shale; no distinguishable fossils have been found in them. No beds of Barakar or Talchir age have been detected, and the base of the sedimentary succession is not seen, whilst an attempt to discover coal by boring proved unsuccessful. Archæan rocks appear in one place along the southern edge of the sandstone, and have apparently been brought up between two faults which throw in opposite directions and which meet each other at both ends.[1]

Inliers near Narkher and Kalmeshwar in Nagpur.—A few miles east of Narkher, thirty miles northwest of the town of Nagpur, and near the villages of Chorkheri and Kutkheri, are two small inliers of Kamthi sandstone exposed beneath the Deccan Trap and very close to each other. A third but larger inlier of the same beds laid bare in the same way occurs near the village of Bazargaon, a few miles W.S.W. of Kalmeshwar and about twenty miles west of Nagpur. The only rocks found are coarse, gritty, felspathic sandstones, and occasional bands of hard compact shale, red or yellow in colour; in the Bazargaon inlier some of the sandstones are conglomeratic. Fossil plants found near Bazargaon prove the beds to be the equivalents of the Raniganj, Bijori or Kamthi formations. No trace of Barakar rocks has been detected in any of these inliers, and borings put down at Bazargaon failed to find any coal. The existence of these inliers indicates that similar beds in all probability underlie the traps in this part of the country over a considerable area.

Kamthi area.—A few miles north of the town of Nagpur, there appears at the edge of the Trap area a small exposure of Gondwana rocks which extends from the vicinity of Kamthi Cantonment for some 25 miles northwestwards as far as the small town of Kelod; the greatest breadth of the exposure is 9 miles, and its area is a little over 100 square miles. Its northeastern boundary with the Archæan rocks of the Central Provinces appears to be approximately straight and is probably a fault; it is, however, ill-seen throughout the greater portion of its length owing to the presence of thick alluvial deposits which conceal so much of both the Gondwana sandstones and the gneisses. The southern tortuous boundary from the edge of the Trap appears to be one of deposition on the gneiss. The only groups represented in this well known and extensively quarried tract are the Talchirs and Kamthis.[2]

Talchir rocks are found in two places. The first of these is on the southern edge of the tract a few miles north of Nagpur, exposed in stream-courses just east of the road connecting Nagpur with Chhindwara. The beds consist of reddish and olive-grey shales which contain large rounded boulders of metamorphic rocks and of the characteristic Vindhyan quartzite-sandstone and limestone. The Vindhyan fragments appear to have come from a considerable distance, since no outcrop of this formation is known near Nagpur. The other Talchir locality is a small isolated hillock of vertical beds known as Koda Dongri ; this is surrounded by alluvium and lies midway along the faulted northeastern edge of the tract.

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[1] W. T. Blanford. *Mem.* VI, pt. 3,115 (1869).

W. T. Blanford. *Mem.* IX, map, p. 330 (1872).

The beds, here seen in their type locality, have already been described. They occupy the rest of the Gondwana area and are well seen at Kelod, also southeast of Saoner, and again south of Patan Saongri, as well as along the edge of the traps from Tondakheri to Bhokara ; the best known exposures, however, are at Silewara, nine miles north of Nagpur, and at Kamthi. At both these places numerous fossils have been obtained from large quarries. The most characteristic beds are the coarse felspathic sandstones, brown, red or white in colour, with bands of hard ferruginous grit, and the compact yellow and red shale. There is no trace of carbon in the plant fossils and, as the Barakars appear to be completely absent in the area, there are no prospects of the occurrence of coal.

Bandar coalfield.—Around the town of Chimur, about thirty miles northeast of Warora and nearly fifty miles S.S.E. of Nagpur, there is exposed in the Chanda district a tract of Talchir beds about 18 miles in extreme length from north to south and about 10 miles broad. In the northwest corner of this exposure is a small triangular basin, occupying about 12 square miles, composed of Kamthi beds resting upon Barakars and known as the Bandar coalfield. The Gondwana tract as a whole is covered to the north and northwest by infra-trappean Lameta beds and Deccan Trap. To the east and west the Talchirs rest upon Archæan metamorphics, while to the southwest and south they lie upon the Sullavais (? Vindhyan), though most of the boundary is concealed by alluvium. The greater part of the Damuda outcrop is made up of Kamthi beds which are unconformable to the Barakars and overlap them to the northeast, but that the older stage underlies the greater part of the Kamthi outcrop has been proved by boring. Three or four seams of coal have been shown to exist and in the opinion of Dr. Fox it can be safely accepted that 18 feet of coal in one, and two or three workable seams, are available under an area of six square miles.[1] The presence of this field was deduced by Mr. T. W. H. Hughes about 1872, in spite of the absence of any actual coal outcrops. The thickness of the Barakars underlying the Kamthis is not known, nor is the extent to which the older rocks had been eroded before deposition of the Kamthis. The character of the Gondwana rocks of this area differs in no appreciable respect from that of the equivalent sediments in the neighbouring Wardha field.

Outliers near Khair and Arjuna.—Before describing the main Gondwana area in the Godavari valley, brief notice may be taken of some outliers to the west of the northern portion. Near the village of Khair, about twenty-five miles west of Chanda town, a considerable area of sandstone is found extending for some five miles up a valley between low hills of Deccan Trap. A smaller tract of similar sandstone, greatly hardened, is again seen to the south in the Yedurba stream, which is chiefly supplied by a copious hot spring close to Khair. Two other small outcrops, mutually separated by overlying trap, are met with about three miles to the southwest, and a larger tract of irregular shape occurs still further to the southwest, around the village of Arjuna, nine miles southwest of Khair. All these beds are covered by trap to the north and west ; they are very ill-exposed but appear to rest upon the limestones of the Sullavai series to the east and south.

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[1] *Mem.* LIX, 330 (1934).

In places, the beds of these outcrops are so greatly indurated that it was at first doubtful whether they could be identified as belonging to any known formation. This is especially the case with the rocks on the Yerduba stream and near Arjuna. The beds in the valley northwest of Khair, however, have the usual characters of the Kamthis, while the recognition by Mr. Hughes of Talchir sediments at the southern extremity of the Arjuna outcrop makes it almost certain that all the rocks in question must belong to the Gondwana system. No exposure of typical Barakars has been recorded, but the occurrence of this stage beneath the Kamthis is not unlikely.

Wardha valley, or Chandal-Yeotma-Adilabad area.—The large area of Gondwana rocks in Chanda and what used to be known as southeast Berar, received early attention on account of the exertions made to procure therefrom a supply of coal for parts of the Great Indian Peninsula Railway. It forms the northwestern portion of an immense tract of the Gondwanas stretching for a distance of about 285 miles from northwest to southeast with a maximum breadth of about 35 miles. This area is traversed throughout by the Wardha river, which forms a convenient but artificial southeastern boundary where it turns eastward to unite with the Wainganga to form the Pranhita ; at this point the Gondwana tract has narrowed to about 14 miles across.

The tract northwest of this artificial boundary, now under consideration, is about 70 miles in length from northwest to southeast, and nearly 30 miles broad where widest ; its area is about 1,600 square miles, and its northwestern termination is about fifteen miles north of Warora. The field may be looked upon as a trough between two great parallel N.W.-S.E. faults, one forming the northeastern boundary from end to end, whilst the other forms the actual boundary only where the field is broadest, disappearing to the northwest beneath the Trap, and dying out in a southeast direction. The Gondwana rocks, where most developed in the neighbourhood of Chanda, are bent into an anticlinal fold whose axis lies much nearer to their southwestern than to their northeastern limit. They dip towards the boundary on each side of this axis, along which the old Purana floor-rocks (Pakhals) crop out in one or two places and in a northwest direction divide the Gondwana outcrop into two arms ; each of these arms extends northwestwards alongside one of the boundary faults till covered up by the trap. Where the southwestern boundary fault dies out in a southeast direction, the area assumes the uniform aspect of rocks dipping steadily at a low angle to the E.N.E. and abruptly cut off in that direction. The rocks bordering the Gondwana tract on the southwest are the shales and limestones of the Pakhal series ; with one or two patches of what may be the Sullavai sandstones ; on the northeast border the rocks consist of Archæan gneisses and the Sullavai sandstones.

The Gondwana groups exposed in the Chanda area are the following :

- Upper Gondwana .
  - Chikiala sandstone ;
  - Kota stage ;
  - Maleri stage
- Lower Gondwana .
  - Mangli series (Panchet) ;
  - Damuda series . . .
    - Kamthi stage ;
    - Barakar stage.
  - Talchir series

The Talchirs cover an area amounting altogether to about 250 square miles, and must be of considerable thickness. The largest tract, west of Chanda town, is partly concealed by river alluvium and interrupted by inlying outcrops of Pakhals. They also stretch for about 15 miles along the southwestern edge of the field, in the Nizam's territory, south of Rajur, and they are found as a very narrow fringe along the northeastern edge of the western arm of the Gondwanas northwest of Wun. The beds are of the usual type, and the basal shales contain boulders. At Irai, on the Penganga not quite a mile above its confluence with the Wardha, Fedden found boulders with polished and grooved surfaces, whilst the underlying Pakhal limestone was seen to be extensively scoured, grooved and polished, the striae running in long parallel lines in a direction approximately N.E.-S.W. Some flexible sandstone has also been found in the Talchir beds south of the Peuganga.

The Barakars are very thin, nowhere exceeding 250 feet in thickness and often less. Their general descending section is :—

4. A very thick band of coal and carbonaceous shale ;
3. Sandstones and shales ;
2. A few thin carbonaceous beds ;
1. Sandstones and shales.

The sandstones, which need not be described, are usually the only Barakar beds seen at the surface. In some places Barakar sandstone rests upon the coal band, but over a considerable area the latter is overlain immediately by the Kamthis. The coal band (No. 4) is an irregular mixture of coal and carbonaceous shale, the proportions of the two varying in almost every one of the numerous bore-holes by which it has been proved ; as a rule, the greater portion consists of coal, some of it of good quality, the rest having a high ash-content. Some thin seams, none of them over two feet in thickness, are found in the lower carbonaceous horizon.

The Barakars are most irregularly distributed, and are overlapped throughout a large area by the Kamthis. They appear in one spot about six miles north of Warora, but coal has not been proved here. Coal-bearing Barakars are to be found in a small tributary of the Wardha six miles W.N.W. of Warora ; the dip is here southwest and the coal doubtless extends under the trap in this direction. Coal was found to underlie the alluvium near Warora, and two of the Barakar coal seams were worked from 1874 to 1906 in the Warora area, but the colliery was shut down as a result of serious subsidence. The next outcrop of Barakars to the south is situated along the arm of Gondwanas already described as extending northwest of Wun. Here a straight strip of the beds, about a mile in breadth and dipping southwest, has been traced for eight miles from northwest to southeast and further southeast by boring ; this area is being worked for coal. The rocks of this strip may be continuous under the alluvium and the Kamthi sediments with another Barakar area further east and southeast, stretching for about twenty miles with interruptions from points west of Bhandak to a point on the other side of the Penganga, W.S.W. of Chanda ; this belt, which includes the thick coal of Telwasa and Ghugus, borders the main Talchir outcrop west of Chanda until overlapped southwards by the Kamthis. Some of the coal is of good quality and there is an aggregate thickness in places of 50 or 60 feet of coal. The Barakars reappear on the other side of the anticline, around Sasti, a village on the other side of the Wardha opposite Ballarpur, and are feebly represented near the town of Chanda, where the upper horizons, including the thick coal, appear to be absent ; north of Chanda they are completely overlapped by the Kamthis. Borings in the outskirts of the town, however, have encountered coal, one colliery having found a 19-foot seam at 81 feet and a 26-feet seam at 120 feet. From the collieries of Ballarpur and Sasti, the annual production of coal during the first ten years after the Great War of 1914-1918 varied from 150,000 to 200,000 tons, but the latter figure has been exceeded since by Ballarpur alone; the reserves of coal in the neighbourhood are estimated to be large. The most southerly Barakar exposure of the tract now being discussed extends for 12 miles from Sirsi, a village seven miles south of Rajur, to Antargaon, whose railway station is situated on the outward side of the angle made by the Wardha river where it bends eastwards to join the Pranhita. North of Sirsi the Kamthis completely overlap the Barakars. A 6-feet seam of coal is known to occur in this locality.

More than two-thirds of the whole Gondwana outcrop is composed of the Kamthis which occupy all the eastern and northeastern portion of the tract, as well as a large area in the west around Wun. They are unconformable to the Barakars, and overlap them in many places to rest generally upon the Talchirs but occasionally upon the Pakhals. Except that they comprise in some places beds of red, yellow and grey clay, they are of the same character as the type beds near Nagpur. The porosity of the coarse, friable, basal Kamthi sandstones enables them generally to be distinguished from the sandstones of the underlying Barakar group, even when the Kamthi beds are deficient in the ferruginous bands so frequently associated with them. These sandstones average 400 or 500 feet in thickness; the town of Chanda is built upon them, and they are well seen on the banks of the Wardha below the coal-pit at Ghugus, west of Chanda. Clays and shales are occasionally interstratified, but neither the argillaceous beds nor the hard irregular ferruginous bands are invariably found. Fossils are of rare occurrence, but some fine fronds of *Glossopteris* have been discovered in some shales near the base of the group in the vicinity of Chanda. The upper beds of the group are usually poorly exposed; they occupy the wild forest country east and northeast of Chanda, sometimes rising in low hills but more often concealed by their own thick debris of sand and clay; a few outcrops of these rocks are seen south of Wun, and in Wardha below Chanda, but no connected section is anywhere exposed. It is consequently impossible to estimate the thickness of the Kamthi series with any accuracy.

Mangli, the type locality of the Mangli stage, is a deserted village at the extreme northwestern end of the Gondwana tract, below the edge of the Trap, ten miles north of Warora. The beds of this stage resemble typical Kamthi sediments but are probably nearer the Panchets in age. They attain a considerable thickness and are described as consisting of compact grits, breaking with a conchoidal fracture and ringing under the hammer, fine or coarse sandstones with red blotches and streaks upon a whitish, yellow or brownish red surface, very fine-grained, compact, homogeneous sandstones having an argillaceous appearance but apparently free from clay, in colour buff weathering to deep red, and ferruginous sandstones and conglomerates containing small quartz pebbles. They occur about 600 or 700 feet above the base of the Kamthis, and have yielded the *Brachyops*, *Estheria* [*Cyzicus*] and other fossils already described (page 964). From similar beds about sixteen miles due west of Chanda around Kawarsa and Panwat have been collected *Estheria* [*Cyzicus*] *mangaliensis*, *Phyllotheca indica*, *Glossopteris* *indica*, *G. browniana*, and fragments of *Schizoneura*. The same beds are found on the same line of strike on Balar Hill between Panwat and Wun.

The tract of Upper Gondwanas straddling the river Wardha in the extreme southeast of the tract under description probably belongs to the Maleri stage a group referred provisionally to the lower Mahadeva. This tract is but the northern extremity of a large area of these and higher Gondwana beds which extend southeastwards far beyond Sironcha; it stretches a few miles north of the Wardha under the patch of alluvium which carries the village of Dhaba (Dabha). On the banks of the Wardha, sections of the characteristic sandstones and clays of the Maleri group are seen; their relationship to the Kamthis is here ill seen but is probably one of unconformability.

No basaltic dykes are known in any part of the Chanda tract, nor indeed in any other portion of the Gondwana area of the Godavari valley. This absence of such volcanic intrusions is all the more remarkable since the Gondwana rocks of the northern end of the Godavari tract disappear westwards under the Deccan Traps, while an outlier of the same igneous suite is to be seen at the southeastern extremity of the whole tract near Rajahmundry. In this particular feature the Godavari region is in strong contrast to the Satpura region.

Central portion of the Godavari valley.—The Central Godavari tract now to be described stretches from the easterly bend of the Wardha, west of the so-called "Third Godavari Barrier" on the Pranhita, southeastwards through the town of Sironcha to within a few miles of Dummagudem (Doomagoodiam) at the "First Godavari Barrier." A broad belt of Gondwana sandstones extends throughout this length of about 140 miles, but the river does not keep within the boundary of the sedimentary rocks. Throughout the greater part of its course, the Pranhita runs to the eastward of the sandstone area, while the main stream of the Godavari, which enters the sandstone area some thirty miles above the junction with the Pranhita, flows into a tract of ancient Pakhal rocks about twenty-five miles below this junction and two or three miles above the confluence of the Indravati. From this point the Godavari makes its way through the Pakhal beds for nearly twenty miles, forming that portion of its course known as the "Second Godavari Barrier"; the river then re-enters the Gondwana area, along the margin of which it runs till just above the First barrier at Dummagudem.

This large area of Gondwana sandstones is still but imperfectly known; the country is very wild and for the most part covered with forest, and the surface is much concealed by alluvial deposits. While the northwestern end of this central tract, as already remarked, is characterised by a contraction in width of the Gondwana outcrop, the southeastern end, at a point southwest of Dummagudem, has shrunk to a width of only six miles; across the greater part of the central tract of Gondwanas the width is between 30 and 40 miles. The northeast boundary is nearly straight and coincides in all probability with an extensive fault. The southwest boundary, which in a general way exhibits a trend parallel to the northeastern, has straight sections which are fault lines échelonned on one another and trespassing into the Gondwana tract sometimes for considerable distances, the southern half of the southwest boundary, however, is more winding and presents the appearance of a depositional contact. It would seem, therefore, that the trough structure of the Wardha valley tract no longer exists throughout the central tract, for, while the fault bounding the trough along the northeast persists that along the southwestern boundary soon becomes échelonned and dissipates itself. Several cross faults have been mapped.

At a short distance south of Wardha, the Gondwana area, as a result of the échelonned faulting, becomes much broader, and the rocks are bounded on the west by the Sullavai beds, except where the Deccan Trap conceals the contact, as far as the Godavari. South of the Godavari, the rocks in contact with the Gondwanas along their southwestern boundary, in order from northwest to southeast, are : Archæan gneiss ; a short belt of Pakhals ; a long belt of Sullavais ; a long belt of Pakhals ; and finally Archæan gneiss stretching thence to the khondalite outcrops of the coastal area. Along their northeast boundary the Gondwana rocks are in faulted contact, first with Archæan gneiss in the north, then for a long distance with the Pakhal beds as far as the neighbourhood of Dummagudem, where the bounding rocks are alternately Pakhals and gneiss. Throughout a considerable portion of this Gondwana tract there is a low dip of the beds to the northeast, so that the lower beds, as a rule, are exposed along the southwestern margin, while the higher beds abut against the northeastern boundary of the tract.

The greater portion of the area consists of coarse sandstone, more or less conglomeratic. The groups known to be represented are as follows :

Upper Gondwana .	Chikiala sandstone ; Kota beds ; Maleri beds.	
Lower Gondwana..	Damuda series .	Kamthi stage Barakar stage.
	Talchir series.	

Talchirs have been found in a few places only. Between the échelonned fault in the northwest, they fringe the Barakars or Kamthis, lying upon the Sullavai or Archæan. West of Jangaon, they can be followed westwards for several miles up a small stream, laid bare beneath the Deccan Trap. A few miles west of Sironcha, a narrow strip of these rocks and an adjacent patch of Sullavais have been brought up in the middle of the tract by a continuation of one of these faults. A long irregular fringe of Talchir beds separates the Kamthis from the floor of Sullavai beds northwest and southeast of the village of Sullavai. Lastly, four or more small outliers, lying indiscriminately upon the Pakhals or the gneiss, are to be seen in the southeast at and around Dummagudem, the most northerly of these, near Cherla, being accompanied by a small outcrop of Barakars. In the exposures of the northwest, the typical Talchir shales are rare, the group consisting chiefly of sandstone, with a well developed boulder bed.

Barakar exposures are smaller and fewer even than those of the Talchirs. The most northerly is a small outcrop, some ten miles south of that of Antargaon, lying on the Sullavais and overlapped by the overlying Kamthis ; no coal seams are here seen. A more important outcrop, though not more than a mile in width, extends from northwest to southeast past the small town of Tandur for about 25 miles, overlying an equally narrow strip of Talchirs and followed by the Kamthis ; two seams of coal are in process of being worked. South of Tandur, at Waripet, is another tiny Barakar outcrop, faulted against the Sullavais on one side and overlying Talchir beds on the other. Accompanying the thin strip of Talchirs a few miles west of Sironcha is an equally narrow outcrop of Barakars about 14 miles long, overlain and overlapped by the Kamthis ; fragments of coal have been found in the Godavari which crosses the outcrop. The Barakars of the small exposure on the left bank of the Godavari, between Dummagudem and Cherla carry the village of Lingala and have rather a high dip; three or four thin seams of coal are known to exist. These beds reappear on the Hyderabad side of the Godavari.

In the large tract of the Kamthis and to the west of Dummagudem, there are several places in which coal or Barakar outcrops have been noted. Such occurrences have been reported in the Kinarsani Vagu three miles east of Bandala, and further down the valley between Gundala and Muttaparam, and as far as Allapalli. These small inliers are in line with the small outliers situated beyond the border of the main Gondwana tract, south of Sullavai; these are referred to later on.

The Kamthi beds stretch uninterruptedly from end to end of the area and occupy a large portion thereof; they must be very thick. The greater portion of them, however, consist of brown ferruginous sandstones without any special characteristic, and as a rule, it is only towards the base that distinctive beds occur. The presence of the porous, coarse, friable sandstones, so typical of the lowest horizons of the group in the Wardha area, makes it easy to define the lower limit of the Kamthis and to separate them from the underlying groups, but their upper margin is far less easily determined with accuracy. The compact red and buff shales, as well as the typical grits breaking with a conchoidal fracture, are less common south of the Wardha than they are to the northward. South of the Godavari, in the neighbourhood of the Maner river, and south of Madapur near Sironcha, a thick succession of sandstones, mostly soft, fine-grained, and yellow, salmon-red and reddish brown in colour, is now included in the Kamthi series; amongst these beds is a fine-grained, salmon-red sandstone with fragments of purple shale.

The Upper Gondwanas occupy all the northeastern portion of the tract, from the Wardha to below the Second Barrier on the Godavari, a distance of nearly 100 miles; for some distance these beds average more than 20 miles in width, and at one spot occupy practically the whole breadth of the Gondwana outcrop. As already explained, the limit between the Kamthis and the Upper Gondwanas, especially south of the Pranhita-Godavari confluence, is somewhat doubtful. So far, the Upper Gondwanas have not been recognised as far south as Dummagudem. In the extreme northwest, near Jangaon, the Upper beds have completely overlapped the Lower so as to rest directly on the underlying Pakhals. At the same time, there is as usual a very close accordance in dip and strike between the Lower and Upper divisions, the beds in each case having the same northeasterly dip, and no marked break can be detected between the two.

The large type-exposure of the Maleri red clays succeeds the Kamthis east of Tandur; its composition and fossil contents have already been described. Two smaller tracts are seen farther north, fringing another outcrop of the Kamthis, and stretching northwards to the vicinity of Dhaba. Another outcrop accompanied by some of the Kota beds has been let down by a fault against the strip of Talchirs west of Sironcha.

The Kota beds, which overlie the Maleris, consist principally of coarse, loosely compacted sandstones, with some subsidiary bands of shale, and three thick bands of limestone; from the last have been obtained all the animal remains characteristic of the group, the few plants having been all derived from sandstone bands. The presence of one small exposure of these beds west of Sironcha has already been noted. The main tract lies east of Sironcha and stretches continuously from a point three or four miles south of Dhaba in the north, southeastwards to the Pangadi Vagu near its confluence with the Godavari, but it no doubt continues for some distance in this direction under the alluvial deposits of the latter river. The Kota beds overlap the Maleris and for over fifty miles, both to the north and south of Sironcha, lie upon the Kamthi beds. Reference has already been made to the fauna and flora of these beds which are now believed to be considerably younger than the Maleri.

The unfossiliferous Chikiala sandstones and conglomerates have been traced for 68 miles along the northeastern boundary of the Gondwana tract, lying upon the Kota beds with a suspected but slight unconformity; the beds are highly ferruginous and have furnished the ore used by the local iron smelters. Thin coal seams form part of the succession. The very doubtful occurrence of Chikiala beds at Balanpur, southwest of Jangaon, has been mentioned in earlier pages.

Outliers north and east of Pakhal Tank.—West of the small village of Kothapali, situated S.S.E. of Sullavai and some twelve miles northeast of the Pakhal tank is a tiny outlier of Lower Gondwana rocks, all dipping at a considerable angle to the W.S.W. and cut off in this direction by a N.N.W.-S.S.E. fault. The beds of this outlier—the so-called Kamaram coalfield[1] —occupy the small valley of the Pangadi Vagu, and lie upon Sullavai rocks. The Talchirs extend round the northeastern edge of the field; along the southwestern, for at least part of the distance, the Barakars and Kamthis abut against the old Pakhal rocks by which the field is surrounded. The Talchirs are the usual fine olive shales, with boulders in places. The Barakars extend for nearly a mile-and-a-half, but their breadth is slight since only about 300 feet of them appear to be present. They rest with a clear unconformity upon the denuded edges of the Talchirs in some places, and include two seams of moderately good coal, one nine feet, the other six feet, in thickness. The high dip, the heavily watered strata, and difficult country detract from the value of this small area.

Singareni.—The Singareni coalfield is a small outlier of Lower Gondwana rocks eight or nine miles southwest of the margin of the main Godavari exposure, and forty miles or more W.S.W. of Dummagudem; it lies within the confines of the Hyderabad State and takes its name from the large village of Singareni, situated about four miles west of the southern termination of the outlier. This tract belongs to the drainage of the Muner, a tributary of the Kistna, and covers an area of about 19 square miles. It has a length of 12 miles from N.N.W. to S.S.E. and an average breadth of a little under two miles. The groups exposed are the Talchir, the Barakar and the Kamthi.

The Talchirs occupy the northern portion of the field only, and consist of the usual fine-grained olive shales, boulders being uncommon though not entirely wanting. The Barakars are distinctly unconformable to the Talchirs, and the irregular distribution of the Kamthis and Barakars is probably also due to unconformity, the former overlapping the latter and resting sometimes on the Talchirs and sometimes on the old Pakhal rocks or the gneiss.

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[1] The name is unfortunate since the maps show three villages within twenty miles of one another, each bearing the name of Kamaram (Kamawaram). The local Kois apparently have a habit of shifting the site of a village if considered necessary.

The Barakars are found in several detached areas, separated from each other by intervening Kamthi beds; they are at least 700 feet thick. Of the two largest areas, one occurs about the middle of the field, and the other along its western edge near the southern extremity. In the former a seam of coal was observed at the surface, but several additional seams have been proved by boring, one of them consisting of quite 34 feet of coal; at a lower depth the so-called "Thick seam" comprises 73 feet of coal, shale and sandstone. Some 214 feet below the Thick seam is the King seam, 7½ feet thick in places. Much of the coal is of excellent quality. Well over 20 million tons of coal have been produced from the Singareni collieries since 1893, when the mineral first began to be raised.

Two small outliers of Kamthis lie upon the Pakhals between the Singareni coalfield and the southwestern edge of the main Gondwana tract.

Southeast extension of the Godavari region.—The southeastern portion of the Godavari basin is a well-defined area, joined to the remainder by the narrow neck already mentioned, southwest of Dummagudem. The Lower Gondwanas, which form the bulk of the exposure, are the most southerly occurrence of these rocks in India. The tract of Lower Gondwanas extends from northwest to southeast for over 50 miles, with an average width of about 25 miles. Towards the southeast it is succeeded by a belt consisting entirely of Upper Gondwana beds, expanding into a much broader area stretching from the Godavari river above Rajahmundry W.S.W.- wards for a distance of nearly 60 miles and ending within twenty miles of the Kistna river at Bezwada.

The boundaries of the tract appear to be for the most part those of natural deposition, in spite of the fact that the southwestern boundary of the Lower Gondwanas is comparatively straight. So far as is known, there is no abrupt junction with the ancient rocks extending for any great distance. The Lower Gondwana portion of the tract rests partly upon the Archæan gneisses and partly upon the khondalites, also of Archæan age; the Upper Gondwana portion lies entirely upon the khondalites and disappear beneath the Deccan Trap west of Rajahmundry and elsewhere beneath the Cuddalore Sandstone (Pleistocene or late Tertiary) and the alluvium of the Godavari and Kistna deltas.

The Lower Gondwana groups represented are the Talchir, Barakar and Kamthi, the last covering probably 99 per cent. of the tract. Of the Talchirs a small outlier is seen lying upon the gneiss outside the northern boundary of the tract. East of this, on the banks of the Godavari below Bhadrachallam, four or five very small outcrops of these beds are observable, most of them fringing Barakar beds. Another occurrence is reported near Kanigiri Hill, along the southwestern edge of the Gondwana tract; here also it is probably in contact with a small strip of Barakars. The irregular distribution of these patches of Talchirs and their general absence at the base of the Barakars appear to indicate a greater degree of unconformity between these two groups than is usually seen elsewhere.

The Barakar outcrops, scarcely larger than those of the Talchir, are found in three localities. One of these is the Madhavaram area, traversed by the Godavari from west to east, a few miles below Bhadrachallam, covering about 24 square miles. The rocks, however, are ill seen and much covered by alluvial deposits; from the few dips observed, it appears probable that some of the boundaries are faulted. Borings have proved the existence of coal seams but these are not thick and much of the coal appears to be of inferior quality. Another tract of Barakar is that of the Baddadanol (Badadanuru) field, thirty-five miles southeast of Bhadrachallam and five miles east of the large village of Ashwaraopet (Ashraopettah). This small field is five miles from north to south and about two miles broad. The Barakars, to the eastward, rest on the gneiss with no intervening Talchirs, and disappear westwards beneath the Kamthis ; both to the north and south, the Kamthis overlap the Barakars. The only Barakar rocks seen at the surface are coarse, grey, white or buff, felspathic sandstones, with ferruginous concretions. At least 600 feet of Barakar rocks appear to be present, the dip varying usually from 2° to 10°. Some inferior coal has been discovered by boring. A third tract of Barakars has already been mentioned as occurring about twenty-five miles southwest of Bhadrachallam, on the southwestern edge of the Gondwana tract ; it is six miles long from northwest to southeast, and two miles across. The Barakars rest partly on Talchirs and partly on the gneiss to the west, whilst to the east they are covered up by Kamthis ; to the northwest they appear to be cut off by a fault.

By far the greater portion of the Lower Gondwana tract is composed of Kamthi beds, though it is possible that further examination may show that some of the strata so assigned belong in reality to higher horizons. The Kamthis of this area are chiefly coarse felspathic sandstones and grits, generally loose in texture, and of various shades of brown, often conglomeratic, and frequently traversed by ferruginous bands. In places, however, white, lilac and red shales occurr, and in some instances, especially along the southwest margin, there is seen the typical compact shale, yellow in colour weathering to red. In the interior of the exposure the Kamthis form large hill-masses, nearly flat-topped, the beds rolling about with very low dips. If the extremely local distribution of the Barakars be due to their extensive denudation before the deposition of the Kamthis, there must be a considerable unconformity between the two groups ; on the other hand, it is possible that the Barakars of this area were originally deposited in isolated patches.

The width of the Upper Gondwana outcrop varies from 10 to 15 miles, and the general dip of the beds is to the southeast at from 5° to 10°. Throughout a considerable portion of their area, the beds rest unconformably upon various members of the Kamthi, but overlap this series both to the northeast and southwest, where they lie upon a sloping floor of khondalite ; this floor has the appearance of a plane of marine denudation, formed after the deposition of the Kamthi rocks, since the latter rest upon a much more uneven surface of the metamorphic khondalites. Such a conclusion is confirmed by the peculiar distribution of the various members of the Upper Gondwanas, which were evidently accumulated in an area distinct from that in which the Gondwana beds of the Godavari valley were deposited.

The beds have been divided as follows :—

3. Tripati sandstones ;
2. Ragavapuram shales ;
1. Golapilli sandstones.

The Golapilli brown and red sandstones and conglomerates, which near Golapilli form a hard plateau capped by the Cuddalore conglomerates and gravels, extend throughout the area from the vicinity of Golapilli to the neighbourhood of the Godavari. Above the Golapillis, about the middle of the area, occur the Ragavapuram shales, which are traceable for about 18 miles, intervening between the Golapilli sandstones and the Tripati beds. The latter, like the Golapillis, extend across the whole area from Golapilli to the Godavari, and are probably equivalent to the Chikiala sandstones of the Godavari region further north. The fossil contents of these beds and their relationships have already been discussed in detail.

Northeast of Rajahmundry and between that town and Vizagapatam there are six very small exposures of Upper Gondwana beds, none exceeding five miles in length and all of them on the edge of the alluvium. The age of these beds is not certain but they appear to represent the Tripati sandstones. The outcrops occur at the following localities, from southwest to northeast: (i) Jagampet (Jaggammapeta), 22 miles E.N.E. of Rajahmundry; outcrop more than four miles in length; (ii) near Kirlampudi, eight miles further to the east; outcrop nearly three miles from north to south by two miles broad, on the edge of the alluvium; (iii) Ayaparaz-Kotapili (Innaparazpalayam), 12 miles further east, on a ridge, two miles long, rising from the alluvium, with ridges of khondalite to the north; the beds consist of purple and brown sandstones, and conglomerates which yielded casts of *Trigonia smeei*, *T. ventricosa*, and other fossils, and are probably the equivalents of the Chikiala sandstones of the Godavari region; (iv) near the village of Jilladypad, four miles further east and a little north; this outcrop occupies a small ridge, 1½ miles long, of brown sandy clay and sandstone, surrounded by alluvium; (v) near the village of "Eedatum", half-a-mile to the northeast; here the bottom beds are hard, coarse, gritty sandstone, brown in colour, and often containing small pebbles; (vi) the last and most easterly exposure, somewhat smaller than the preceding, lies eight miles to the northeast, close to the coast; it is a narrow strip of coarse brown sandstone, about two miles long, resting upon the edge of the khondalite hills of Sudikonda.

The Upper Gondwanas of the Coromandel coast are found not only to the northeast but also to the southwest of the Godavari valley, on the other side of the Kistna delta. In this direction a line of small outcrops can be traced for over a hundred miles to a point fifteen miles of Kandukur (Cundacoor) in Nellore. These outcrops are very numerous but, owing to the manner in which the surface of the country near the coast is covered with laterite, lateritic gravel and black soil, the rocks are ill exposed and in many places can only be detected in well-sections or excavations for tanks. The most northerly exposure hitherto found in the country south of the Kistna delta is close to the town of Guntur; thence to Ongole there is a series of about five small tracts along the edge of the coast alluvium. In these tracts, shales and sandstones very similar to those found at Sripermatur further south are exposed. In well-sections in the town of Guntur, grits and conglomerates lithologically resembling some of the Sripermatur beds are seen. About six miles southeast of the town, there rises from the alluvium a long low ridge, about 14 miles long from northeast to southwest but only about two miles broad; this ridge is made up of compact, brown, reddish and purple, gritty sandstones probably equivalent to the Tripati sandstones, resting upon soft white shales with ferruginous partings, doubtless identical with the beds of Sripermatur and Ragavapuram.

Southwest of Guntur, the two most important outcrops are those at Inkollu (Yinkolu), twenty-six miles N.-by-E. of Ongole, and at Vemavaram (Wamayavaram), midway between. In each case the beds have been traced over from 12 to 15 square miles. In the Inkollu outcrop, at the village of Budavada, three-and-a-half miles W.-by-N. of Inkollu, limestones and calcareous sandstones have been found containing large numbers of oysters, besides ammonites and molluscan shells; these marine fossiliferous Budavada beds, which have already been described (page 1003), are the upper bands of a group of gritty sandstones, and appear to lie at a slightly lower horizon than the sandy shales which are seen east of the village and which have yielded a flora corresponding more or less to that of the Ragavapuram shales. Above the shales is a hard sandstone, which forms a small plateau northeast of Budavada, and which may very likely represent the Tripati group. Near Vemavaram, a much greater thickness of beds is exposed, consisting of white, buff and purplish shales, with flaggy beds and thin bands of sandstone; some of the higher horizons have yielded marine fossils (page 1003). Another outlier is found at Yendlur, six miles W.-by-N. of Ongole, and from some clays and sandy shales therein a few plant remains, including a *Ptilophyllum*, have been obtained. At this spot occurs some indurated sandstone whose relationship to the shales is obscure.

South of Ongole, several other small outcrops of Upper Gondwana beds have been detected, the principal one being west of the town of Kandukur, twenty miles S.S.W. of Ongole, while some highly fossiliferous shales are exposed in well-sections in Kandukur itself. It is evident that these beds, which are the equivalents of the Ragavapuram and Vemavaram groups and contain many of the usual Rajmahal plants, occupy a considerable area beneath the surface covering of laterite. The most southerly exposure of the rocks in this neighbourhood is about fifteen miles south of Kandukur, and west of Ramapatam.

X.—COASTAL OUTCROPS IN THE NEIGHBOURHOOD OF MADRAS CITY, NORTH AND SOUTH OF THE PALAR RIVER.

South of the last-mentioned exposure of Upper Gondwanas—that to the south of Kandukur—no further outcrops are seen for over a hundred miles, when they recommence in the Madras area along a N.-S. line 80 miles long, on each side of the Palar river. These, usually spoken of as the Sripermatur outcrops, occur along the edge of the Archaean gneiss, intervening between it and the laterite or alluvium of the coast, or as outliers scattered over the surface of the gneiss, or in one case as an inlier beneath the alluvial gravels of Conjeveram. The beds are not found more than fifty miles from the coast. Borings in this area failed to find any trace of coal or Lower Gondwana beds.

The largest expanse of Upper Gondwana beds in this neighbourhood forms an interrupted tract to the northwest and west of the city of Madras in the vicinity of Sattavedu, Alikur and Pyanur. The southern extremity of this tract is traversed by the Madras Railway at a distance of thirty-seven or thirty-eight miles from Madras, a little east of Arkonan junction. The outcrop extends from north to south for about 35 miles, being interrupted only for short distances by the alluvium of the Narnaveram (Narayanavaram) and Nagari rivers, which divide it into three more or less equal portions, near Sattavedu, Alikur and Pyanur, respectively. The width of each of these portions is from five to six miles. In all of them, the sandstones of the Gondwana system rest for the most part on Archaean gneiss but in one instance on Cuddapah rocks to the west, and disappear eastwards beneath laterite and alluvium, large outliers being scattered over the Gondwana sandstones.

Considering this tract as a whole, the northern portion consists of the Sattavedu group, made up chiefly of coarse compact conglomerate. This occupies the whole of the Sattavedu area north of the Narnaveram river, and the greater portion of the central Alikur area. The southern portion of the latter, as well as the whole of the area near Pyanur, south of the Nagari river, is composed of shales, sandstones, uncompacted conglomerate, and boulder beds, belonging to the Sripermatur group ; the boulder bed is always found at the base.

The next outcrop is that of Sripermatur, situated southeast of the Pyanur area and separated therefrom by the alluvium of the Cotteliar (Korttalaiyar) river and an expanse of lateritic gravel. The length of the outcrop from north to south is about fifteen miles ; the width in the north is about nine miles but diminishes to the south. The Gondwana area is surrounded by lateritic gravel, but metamorphic rocks appear here and there through the superficial covering, whilst inliers of the Gondwanas show that these beds exist in places beneath the laterite. The base of the Gondwana deposits is nowhere seen. The whole of this tract is composed of the Sripermatur group ; to the northward, shales prevail and rest upon gritty sandstone, but in the southern portion of the area coarser beds are found. Some of the argillaceous beds show a slight tendency to cone-in-cone structure. The plant remains and the associated marine fossils have already been described.

Outliers of these rocks to the south and southwest are numerous but of small size. One group of nearly thirty—none of them exceeding two miles in length and the majority of them far smaller—is scattered over the country southeast of Conjeveram. Another group of rather larger patches extends nearly in a line, from north to south, to the west of the main road from Madras to Trichinopoly; the largest and most southerly, which is about four miles long and close to the southern border of the Chingleput district, is crossed by the road. All of them consist of Sripermatur beds.

XI.—THE UTATUR PLANT BEDS OF TRICHINOPOLY.

From the boundary line separating Chingleput from South Arcot, there is again a gap of over ninety miles throughout which no Gondwana outcrops have been observed, until the Trichinopoly district is reached. Here there are several isolated occurrences along the western edge of the Cretaceousoutcrop on the north side of the Cauvery or Coleroon river. They all rest upon the Archaean to the northwest, and dip to the southeast under the marine Cretaceous beds, which lie upon them, generally with considerable unconformity but sometimes with no visible discordance. The Gondwanas consist of the Utatur Plant Beds, which had been extensively denuded before the deposition of the Cretaceous rocks of this area. They crop out in five distinct exposures, the most northerly lying between Perambalur and Ariyalur, whilst the southernmost is close to the village of Utatur. The whole distance from northeast to southwest over which they are distributed is about 14 miles ; the three most southerly outcrops are close together, and form a nearly continuous fringe to the Cretaceous sediments for a distance of six or seven miles.

The Upper Gondwanas of Trichinopoly consist chiefly of soft sandy clays and micaceous shales, grey and brown in colour, and at the base coarse ferruginous sandstone containing pebbles and large blocks of gneiss derived from the immediate neighbourhood ; the basal bed is occasionally absent. The gneiss upon which the rocks rest is always greatly decomposed. Plant remains, principally of *Ptilophyllum acutifolium*, occur here and there, but the impressions are rarely well preserved.

Significance of the East-Coast Gondwana occurrences.—The Upper Gondwana beds of the Coromandel coast derive their main interest from their association with beds containing marine fossils, an indication that, unlike the Gondwanas of most other localities, they were deposited on or near the sea-shore. The plant beds may be deltaic or lagoon deposits, and the succession as a whole affords clear evidence of the immediate proximity of an old shore line parallel and very close to the present Coromandel coast.

The beds occur in four groups of outcrops. Two of these groups are continuations of long riverine tracts, one along the Mahanadi valley and beyond for some hundreds of miles, the other extending up the Godavari for a distance of similar magnitude. This being so, it is permissible to ask whether the other two groups of coastal sediments are not also deltaic remnants of similar riverine tracts, practically all of which have been removed by denudation. Those grouped around Madras are distributed on both sides of the Palar river; the latter, although now of much smaller size and importance than either the Mahanadi or the Godavari, seems formerly to have been of considerably larger dimensions, judging from the extent of its alluvial deposits and the distance they penetrate the gneiss westwards. The Trichinopoly outcrops adjoin the delta of the Cauvery, which possesses a still larger expanse of alluvial sediments stretching up the valley westwards for over 120 miles. No relics of these hypothetical Gondwana rivers, however, have been found on the more central tracts of the Peninsula.

The Kota stage of the Godavari valley appears to be represented in northwest Ceylon.

XII.—LOWER NARBADA VALLEY.

Close to Barwai on the Narbada, about a hundred miles below Hoshangabad, and eighty or ninety miles west and a little south of Lokartalai, are some coarse conglomerates with a matrix of clay, occurring beneath another conglomeratic band containing oyster shells. The latter, which belongs to the Cretaceous Bagh beds, is unconformable to the lower conglomerate, which is of small thickness, rests upon the Bijawar rocks, and has been spoken of as Mahadeva; no trace of any Lower Gondwana beds can be detected.

Conglomeratic beds, somewhat similar to those of Barwai, have been traced at intervals throughout a considerable area to the eastward between Barwai and Hindia, intervening between the base of the Trap and various rocks such as the Vindhyan, Bijawar or gneiss. These conglomerates, however, appear to be, as a rule, of later date than the Mahadevas and to represent the Lameta group. Further west is the Nimar Sandstone underlying the Bagh fossil beds.

That these conglomerates and sandstones beneath the marine bands of the Bagh series may be of the same age as some of the Upper Gondwana sediments is not improbable, though they may not be as old as the Mahadeva. Whether the term, Gondwana, is suitable for fresh-water deposits formed under slightly different conditions is a matter of individual opinion and not of much importance. The rift or fault which seems to have initiated the Narbada valley was of considerably later date than the bulk of the faulting which took place during the Gondwana era, and produced a river flowing westwards instead of to the east or southeast. For these reasons, the Narbada deposits are dealt with under the heading of Cretaceous and not that of Gondwana. This is an arbitrary distinction, nonetheless, for the Umia beds of Cutch have been described under the heading of Gondwana, following previous custom. Some limit must of course be given to the term, Gondwana, otherwise it might be not illogically used to embrace such formations as the Lameta, Cuddalore, and even the Indo-Gangetic alluvium.

XIII.—CUTCH AND KATHIAWAR.

The Umia beds of Cutch, which have been described in detail in earlier pages, lie on the western side of the old watershed, and include plant beds associated below with beds containing marine fossils of uppermost Jurassic age, and above with beds containing fossils of Lower Cretaceous (Aptian) age ; the Umia beds themselves, therefore, are probably of Lower Cretaceous age. The Upper Gondwanas of Kathiawar are perhaps not quite so young but are not older than the Jabalpur series.

XIV.—IDAR AND RAJPUTANA.

The Ahmednagar Sandstone, probably the equivalent of the Nimar Sandstone of the Narbada valley, is known to be of Lower Cretaceous age, and corresponds to the top of the Gondwana succession.

In Rajputana are found the only examples of Lower Gondwana rocks to be seen on the western side of the Aravalli watershed. Here the Bap boulder bed is equated with the Talchir boulder bed, and the plant-bearing Lathi sandstones, up into which the Bap bed passes, would appear to correspond to much of the Damuda series. In Rajputana, the highest horizons of the Upper Gondwana are thought to be represented by the Barmer Sandstone.

On the western side of the Aravalli watershed, it is not possible to group the scattered Gondwana exposures into riverine tracts of lines of basins, and their relationships to one another are obscure.

XV.—GARO HILLS OF ASSAM.

Recently, Damuda rocks have been recognised by Dr. Fox at Singrimari in the Garo Hills of Assam. These consist of Barakar-like sandstones and carbonaceous shales with lenticles of coal and numerous impressions of *Vertebraria indica*. The sandstones, which dip westwards into the Jinjiram river, are intruded by dykes of dolerite[1]. Whether this exposure is connected in any way with that of the Rajmahal area, it would be difficult to say ; it is not on the line of the Damuda valley. The exposures in the eastern Himalaya are about the same distance away as the Rajmahal outcrops.

XVI.—EXTRA-PENINSULAR OCCURRENCES.

Salt Range, Himalaya and Hazara.—The exposures in the Salt Range of the Punjab and in the Himalaya of Damuda rocks with coal seams or plant impressions have been described in some detail in Chapter XX. The occurrences in the Salt Range and Kashmir, associated as they are in the former area at least with the Talchir boulder bed, belong to a river or rivers of unknown direction ; all that can be said is that the drainage of this region in Lower Gondwana times probably flowed either towards the north or towards the west, since it lay on the northwest side of the Aravalli range, the main watershed of the Indian portion of Gondwana land. The Damudas of the Salt Range and Kashmir, as proved by their association with marine Permian beds, are of estuarine or deltaic origin, and indicate the immediate proximity of a coast—part of the northern coast of the continent. This portion of the coast became greatly disturbed by volcanic outbursts which continued throughout the earlier half of the Gondwana era. The presence of the Blaini Boulder Bed, the presumed equivalent of the Talchir Boulder Bed, not only in the Simla hills and Hazara but also in Garhwal and possibly below Darjeeling, is proof that glacial conditions prevailed along the north coastal regions of the continent, on both sides of the termination of the old Aravalli watershed. The discovery of what is believed to be representatives of these glacial beds in the northern parts of Sikkim shows that the ice-covered land stretched in this direction beyond the present site of the Great Himalaya range.

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[1] *Mem.* LIX, 51 (1934).

As to the coal-bearing Damudas of the Darjeeling district and other parts of the eastern Himalaya, it would be idle to speculate at the present stage of our knowledge what their relationships are to the occurrence in the Garo Hills or to those in the Rajmahal area, or of what particular old river valley they are relics. No less than ten seams of coal, each over five feet in thickness and containing less than 22 per cent. of ash, have been recognised in one section of the Darjeeling area; were it not for the extremely friable nature of the coal, which has evidently suffered seriously from the Himalayan disturbances, and for its rapid variation in thickness, its exploitation would no doubt have been more successful than it was during the last five years of the preceding century.

Afghanistan and Burma.—It is worth noting that the Saighan series of Afghanistan, with its well preserved plant remains, corresponds in age to some part of the Upper Gondwana division of Middle Jurassic age, but belongs to the northern or Angara continent. To Angaraland also belong the Loi-an coal measures of Burma, which are equivalent in age to the Rhætic or Lower Jurassic portion of the Gondwana succession.

CHAPTER XXIV.

THE GONDWANA CONTINENT.

Introduction.—**Australia** : Victoria ; New South Wales ; Queensland ; Western Australia North Australia ; South Australia ; Central Australia ; Tasmania ; Conditions in Australia ; New Zealand. **South Africa. Tropical Africa.** Madagascar. **South America. The Falkland Islands. Antarctica. Land connection between India and other parts of the Gondwana continent.** Causes of glaciation. **Evolution of the World's floras.** The Northern province. Character of the *Glossopteris* flora. Northern types in the Southern province. Southern types in the Northern province. Communication between the Northern and Southern continents. **The Geography of Asia from Upper Carboniferous times to the end of the Trias.**

Introduction.—Since the last edition of this Manual appeared, the science of Palæobotany has made considerable strides and it has become possible to make use of plant remains for correlation and taxial purposes with a little more confidence than it was when W. T. Blanford complained that "in the Gondwana we have a Rhætic flora overlying a Jurassic flora, and a Triassic fauna above both !"[1] These and other paradoxes have been corrected by further experience and were the result, perhaps in some cases of hasty determination, but mostly of the scanty and disconnected character of the vegetable remains. Change after change has been found necessary until today most of the Gondwana sequence has been correlated in some detail and with some degree of reliability not only with rocks of the same floral province in Australia, South Africa and South America but with those of a different province in Europe and North America. The recently proved Lower Cretaceous age of the Upper Gondwanas of the Coromandel coast may necessitate some further readjustment, unless the plants therein are shown to be derived. This proof rests upon the evidence of ammonites which, though few and fragmentary, are sufficiently determinable to warrant the above conclusion. For the original idea that the East Coast beds belong to the Jurassic as their plant remains appear to do, the responsibility would seem to rest not so much on the palæobotanists as upon the palæontologists who misidentified one of the ammonites as "*Stephanoceras opis*" and assumed that *Trigonia smeei* did not range above the Jurassic.

The age of the various subdivisions of the Indian Gondwana system has been dealt with in each sub-section of the previous chapter, and indicated on the correlation table on page 924-5. The evidence in favour of an Upper Carboniferous age for the glacial epoch in India has been summarised by Sir Thomas Holland[2] and is supported especially by certain bands of marine fossils found in the Australian sequence,[3] and by an association of the *Glossopteris* flora with Carboniferous forms such as *Lepidodendron* and *Sigillaria* in South Africa and South America.

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[1] *Pres. Addr. Sect., C. Brit. Ass.*, Montreal 691 (1884) ; reprinted, *Rec.*, XVIII, 32 (1885).

[2] *Q. J. G. S.*, LXXXIX, lxiv (1933).

[3] This has been recently challenged by Raggatt and Fletcher (*Rec. Austral. Mus.* XX, 150 (1937). who claim that it is "no longer possible to maintain that *Eurydesma cordatum* and *E.hobartense* mark two distinct stratigraphical horizons in Australia", and prefer to draw the boundary between the Carboniferous and the Permian at the base of the Talchir.

Space forbids a survey in detail of the numerous counterparts of the Gondwana system which have been found in many parts of the southern hemisphere and which form contributions to what is now a classical story. At the same time, it is impossible to follow properly the geological history of India from the end of the Carboniferous to the beginning of the Cretaceous without some comprehensive outline of the extent and character of the great Gondwana continent of which it formed a part. The copious relics of this ancient land, and the immensely widespread character of its climate, its flora and its fauna, render its study one of the most absorbing chapters in geological history. Over a vast region including parts of India, Australia, South Africa and South America, we have evidence of an almost continuous succession of plant-bearing, fresh-water sediments, beginning in late Palæozoic and continuing on through the greater part of Mesozoic times. All these regions exhibit a remarkable community in lithological character and conditions of sedimentation. Everywhere this continental succession was ushered in by glacial conditions, and everywhere a general desiccation accompanied by a warmer climate towards the middle of the era was marked by the advent of innumerable reptiles. The final phase was one of disruption and volcanic effusion on a scale which can only be described as colossal.

Australia.—The earliest discovery outside India of rocks comparable in facies and age to those of the Gondwana was made in South Australia in 1859. Here Dr. Selwyn found boulder beds precisely similar to those of the Indian Talchir. Since then many other examples have been found and a very large portion of Australia, including the island of Tasmania, has been shown to be occupied by glacial deposits and superjacent plant-beds homotaxial with those of the Indian Lower Gondwana.

Victoria.—From Bacchus Marsh in Victoria a limited flora, consisting of *Gangamopteris angustifolia*, *G. cyclopteroides* and a *Schizoneura*, has been obtained. This in itself would suggest a correlation of the Bacchus Marsh with either the Talchir or Karharbari beds, but there is further evidence in the presence of large blocks of granite and pebbles of rocks which must have travelled long distances, embedded in a fine-grained matrix of mud. These beds, lying in many cases upon a heavily glaciated surface, consist of tillites and glacial mudstones, with a total thickness of over 1,600 feet. This fact, combined with the palæobotanical evidence, justifies us in regarding the beds as the equivalents of the Indian Talchirs. In this stage, which corresponds to the third or Lochinvar glacial stage of New South Wales, there is evidence of widespread and intense glaciation ; the capping of 30 feet of sandstone, with its abundant *Gangamopteris* impressions, follows with perfect conformity. Most, if not all, of the Damuda equivalents are present, and higher in the sequence come Triassic shales with *Schizoneura*. In the same province, the Mesozoic Coal Measures have yielded a copious flora comparable to that of corresponding beds in the Upper Gondwana ; this flora includes the Indian species, *Thinnfeldia odontopteroides*, *T.*(?)*indica*, *Tæniopteris spatulata*, *Elatocladus plana*, *E. conferta*, and a variety (*australica*) of *Coniopteris hymenophylloides*.

New South Wales.—In New South Wales there is a much better and more complete section which is in fact the standard one for Australian geology, so far as the period under consideration is concerned. The sequence there includes the following groups :

Jurassic	Tibooburra beds. Talbragar series.	Clarence series. (Basal Clarence-Rhætic).	
Trias	Wianamatta series. Hawkesbury Sandstone. Narrabeen series.		
Permian	Upper Coal Measures.	Newcastle Coal Measures. Tomago Coal Measures (including the Dempsey beds).	
	........*unconformity.*		
	Upper Marine series.		(Fifth glacial horizon, A & B).
	Lower or Greta Coal Measures.		
	Upper part of the Lower Marine series.		(Fourth glacial horizon).
	....*slight transgressional break.*		
Upper Carboniferous (Uralian)	Lower part of Lower Marine series.	Lochinvar Marine stage. Lochinvar glacial beds.	(Third glacial horizon).
..	*Phytological and facies break.*		
Middle Carboniferous. Kuttung series. (Moscovian)	Main Glacial stage (with *Rhacopteris* flora).		(Second glacial horizon)
	Volcanic stage (with *Lepidodendron, Ulodendron* and *Pitys*).		
	Basal stage.	Minor glacial horizon. Wallarobba conglomerates and tuffs.	First glacial horizon.
Lower Carboniferous (Dinantian)	Burindi series; marine strata with *Lepidodendron veltheimianum.*		

In the 10,000 feet of rocks allotted to the Kuttung series we have record of a period of severe volcanic activity, with recurrent quiescent intervals during which the valleys were occupied by glaciers. The sediments associated with the tillite at the top of this series have yielded leaves of *Rhacopteris* and *Cardiopteris* and casts of *Archæocalamites*. The only member of the Zygopterideœ, known in the southern hemisphere, *Austroclepsis* [*Clepsydropsis*] *australis* (Osborn), has been found lower down in this series, but not less than 2,000 feet above its base.[1] With the higher portions of this series is to be correlated the Po series of Spiti in northern India.

Marine beds are important on account of the marine fossils they contain and indicate a southward extension of the Tethys Sea. These beds, and especially those immediately associated with the Greta Coal Measures of Stony Creek, are composed of a fine-grained matrix of sand or shale, enclosing numerous delicate Fenestellae and bivalve shells with their valves still united. Scattered through the matrix are numerous sub-angular blocks of rock, of all sizes, ranging up to ten feet in diameter, some of which exhibit glacial striae. The lower of the two glacial beds belonging to the Upper Marine series contains large dumped boulders encrusted with Fenestellidae. The undisturbed condition of the bivalves and other fossils proves as conclusively as does the texture of the matrix in which they are so well preserved, that the shells and polyzoaries could never have been exposed to a current of any appreciable rapidity, but are the remains of animals which lived and died and were tranquilly preserved where they are now found. It was no swift torrent which carried these boulders and deposited them where they now rest, for to move even the smallest of them would require a current that would have been strong enough to sweep away the fine material in which they are embedded, and would have destroyed the delicate fossils with which they are associated. They must have been floated to their present position and dropped on to the bottom of a tranquil sea. Taking into consideration their abundance as well as the distinct traces of glacial action that some of them show, the only agency which can be appealed to seems to be that of floating ice-bergs, and we may therefore conclude that, in New South Wales, the ice sheets of this epoch reached the sea and discharged their burden of moraine upon the fine silty bottom of an ocean in which a marine fauna flourished and died *in situ*.

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[1] B. Sahni. *Phil. Trans .Roy. Soc. Lond.*,B, Vol. 217, 1-37 (1928) ; B. Sahni. *New Phytologist*, XXXI, 270-278 (1932).

Near the base of the upper part of the Lower Marine series occur species of *Eurydesma*, a genus represented, as we have seen, in the *Conularia* stage of the Nilawan series of the Indian Salt Range ; the equivalence of the Lower Marine Glacial stage (Lochinvar Glacial beds) to the boulder bed at the base of the Nilawan series, and the close alliance of the faunas from the two areas have already been referred to (page 752). In the Lochinvar Marine stage occur the oldest known examples in Australia of *Gangamopteris*. The Lochinvar beds, as a whole, appear to correspond closely with the Talchir stage of the Indian Gondwanas. The Greta Coal Measures consist of a comparatively thin band of sandstones and coal, intercalated between the Lower and Upper Marine beds, and contain a restricted flora which includes four typical Indian species : *Gangamopteris cyclopteroides*, *G. angustifolia*, *Glossopteris indica* and *Cordaites* (*Noeggerathiopsis*) *hislopi*. In places, however, these Coal Measures are interbedded with 2,000 feet of volcanic rocks. The Upper Marine series has yielded some fossil wood referable to *Dadoxylon* and some "fucoid" markings. *Strophalosia clarkei* is especially abundant in the Upper Marine series of New South Wales.

The unconformity between the top of the Upper Marine series and the base of the Upper Coal Measures is pronounced and in one place represents an erosion of some 4,000 feet of strata. *Glossopteris* fronds and cordaitean trees, mostly *Dadoxylon*, are found in the Tomago series. The same trees in the Newcastle stage reach dimensions of three feet across and about 120 feet in height. On several horizons in this stage fossil forests have been recorded, with trees in an erect position and roots spreading near the surface of the coal seams, preserved in many cases by the volcanic ashes which killed them. That the Newcastle stage belongs to the top of the Permian is indicated in the first place by its remarkable assemblage of fossil insects, preserved largely by the agency of the rhyolitic tuff, and in the second place and by its labyrinthodonts, *Bothriceps australis* and *B. major*, forms akin to the *Brachyops laticeps* of the Indian Damuda. The flora of the Dempsey is very similar to that of the Newcastle stage which includes the following forms :[1]

Algae—

Reinschia australis Bertr. & Ren.,
Pila australis Brongn.

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[1] B. Sahni. *Proc. 13th. Ind. Sci. Congr.*, Chart III (1926).

Equisetales—
Schizoneura gondwanensis Feistm.,
Phyllotheca australis Brongn.,
,, *deliquescens* (Goepp.),
,, *etheridgei* Arb.

Pteridospermae and Filicales—
Glossopteris browniana Brongn.,
,, *indica* Schimp.,
,, *ampla* Dana.,
Vertebraria australis McCoy (? = *V. indica* Royle.),
Gangamopteris cyclopteroides Feistm.,
,, *angustifolia* McCoy.,
Sphenopteris polymorpha Feistm.,
,, *lobifolia* Morr.,
,, *alata* Brongn. sp.

Cordaitales—
Cordaites (*Noeggerathiopsis*) *hislopi* Bunb.,
Dadoxylon arberi Sew.[1]

Incertae sedis—
Cordaicarpus sp.

Not only are there close specific relationships with the Damuda flora but there is a general resemblance in the type of the floras as a whole ; the principal and more characteristic genera of the Newcastle beds are represented in the Damudas, and in both formations the genus *Glossopteris* constitutes about one-third of the total number of species. The palæobotanical evidence would of itself be sufficient to justify the correlation of the Newcastle with part of the Damuda series and, bearing in mind the general position of each with regard to the glacial beds lower down in the sequence, it becomes certain that the two coal-bearing series must be to a large extent equivalent.

The Trias in New South Wales is represented by the Narrabeen series, the overlying Hawkesbury Sandstone, and the Wianamatta beds,[2] all of them plant bearing and corresponding to the Panchet in India. The succession which followed the Marine series, including the Tomago, Newcastle, Narrabeen, Hawkesbury, and Wianamatta, are thought to represent epochs of great fresh-water lakes, river flats and swamps. The Upper Permian and Trias of Australia have furnished a unique collection of fossil insects which include : dragonflies in abundance, cockroaches, beetles, silky lace-wings, caddis flies, house flies, scorpion flies, stick insects, locusts, silent cicadas, grasshoppers, and a large moth. The labyrinthodonts of the Australian Trias are not numerous but include *Platyceps wilkinsoni* which is perhaps a young individual of the Indian and South African *Batrachosuchus*.

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[1] Equivalent to *Araucarioxylon daintreei* Chapm. [B. Sahni. *Journ. Ind. Bot. Soc* V., 103 (1926)].

[2] Following David & Süssmilch. B. Sahni, however, calls attention to the fact that palæobotanically the base of the Narrabeen formation is still a part of the Palæozoic (*Proc. 13th Ind. Sci. Congr.*, 245 (1926).

The sequence in New South Wales differs, however, from the Indian in certain particulars which are of great interest and importance. In the first place, there are no less than five glacial horizons of late Palæozoic age, the youngest separated from the oldest by a thickness of at least 11,000 feet or, if maximum thicknesses be taken, 15,000 feet. In the second place, the first of these five glacial epochs dates back to the basal stage of the Kuttung series and is, therefore, to be correlated with the base of the Middle Carboniferous ; it is a glacial horizon of minor importance, occurring considerably earlier than that of the Talchir or than the advent of the *Glossopteris* flora. The Kuttung series passes down with no angular unconformity into the Burindi, a series with an abundant marine fauna of Lower Carboniferous age. The middle stage of the Kuttung, a series deposited under terrestrial conditions, contains remains of *Lepidodendron, Ulodendron, Austroclepsis*, etc. Occupying the top of the Kuttung, the succeeding glacial stage which is some 4,700 feet in thickness and is the principal glacial stage of the Australian sequence, is associated with a *Rhaeopteris* flora—a widely distributed plant assemblage which preceded the *Glossopteris* flora in the southern hemisphere and was supplanted thereby. The level of this second glacial horizon, which was characterised also by intensive volcanic activity, is equated with the upper portion of the Middle Carboniferous.

It is the third or Lochinvar glacial horizon, forming the basal 300 feet of the Lower Marine series in New South Wales and the equivalent of the top of the Upper Carboniferous, which corresponds to the Talchir in India. Not only does this boulder bed mark a strong phytological break between the *Lepidodendron-Rhaeopteris* flora below and the *Gangamopteris-Glossopteris* flora above, but its dominant boulders and pebbles are of different material from that of the majority of the Kuttung débris ; it also marks a change back from terrestrial and fresh-water to dominantly marine conditions.

Above the Lochinvar marine beds, which are some 2,400 feet in thickness, and forming the base of the upper part of the Lower Marine series, the fourth glacial horizon is represented by glacial erratics in the Annandale conglomerates, in which stage the lamellibranch, *Eurydesma cordatum*, is abundant. The Lochinvar series, though dominantly marine, contains in some localities examples of the *Gangamopteris-Glossopteris* flora. The fifth glacial horizon, consisting really of two well marked zones in close proximity, is found above the Greta Coal Measures with their glossopterids.

Queensland.—Queensland also possesses a representative succession of beds equivalent to the Gondwanas. The approximate equivalent of the Damuda or Permian is here known as the Bowen series, the Trias and Rhætic are represented by the Esk and the Ipswich series, and the rest of the Jurassic by the Walloon series. In Queensland the plant-bearing beds continue up into the Lower Cretaceous.

In this province three glacial epochs have been recognised. The oldest of these corresponding perhaps to the Talchir, is represented by glacial erratics in the marine Gympie series, which is characterised by the productid, *Pustula*, species of *Protoretepora*, and numerous *Stenopora*. The Gympie series and the underlying Dinner Creek beds with their early *Glossopteris-Gangamopteris* flora, occur below the Bowen series and are regarded as of Upper Carboniferous age. Forming the base of the Lower Bowen is the second glacial horizon, associated with banks of *Eurydesma cordatum* and above it come the *Glossopteris* shales and small coal seams of the Springsure beds which are interstratified with marine sediments. The third glacial horizon forms part of the Middle Bowen with its marine fossils (including *Strophalosia clarkei* and the brachiopod, *Derbya*) and dumped glacial erratics ; the Middle Bowen is the equivalent of the Greta Coal Measures and Upper Marine series.

Western Australia.—The sequence in Western Australia is also relatively complete, and the *Glossopteris* flora has been found in the Collie River Coalfield, at the Gascoyne River, and in other localities. In Western Australia the Talchir horizon is probably represented by the glacial beds of the Irwin river and of the Kimberley region ; in the latter case these glacial deposits are associated with beds containing *Dadoxylon*, not only above but also below, in the position of growth. Some small glacial erratics are, however, found above the Irwin River and Collie River Coal Measures in which occur *Glossopteris* and *Gangamopteris* in some abundance as well as other members of the flora. An interesting marine fauna, an element of which is a bank of the cephalopod *Paralegoceras*—including the species *P. jacksoni*—has been obtained from strata immediately below the Irwin River Coal Measures and is believed to indicate an Upper Carboniferous age. From a horizon in the Arthur River beds of Western Australia have been collected the remains of a shark which, if not belonging to the genus *Toxoprion*, is a species of *Helicoprion*, a genus found in the Artinskian of Russia, in the Lower Permian of Japan and in the Upper Productus Limestone of Chhidru in the Indian Salt Range.

North Australia.—In north Australia the Greta Coal Measures are represented by black shales with *Glossopteris* and *Cordaites* (*Noeggerathiopsis*), underlying beds with marine fossils belonging to the Upper Marine series ; the polyzoan, *Dybowskiella geei*, belonging to a genus characteristic of the Productus Limestone of the Salt Range, is frequent and well preserved in these strata.

South Australia.—Glacial beds of the Talchir horizon, lying upon heavily glaciated pavements, are to be seen in the Inman valley of South Australia, as well as some infaulted beds (Leigh's Creek) which have yielded a Triassic flora. No relics of the *Glossopteris* flora have so far been found in this province.

Central Australia.—Glacial deposits, presumably belonging to the period under consideration, cover several square miles in the Finke valley near Crown Point in central Australia. The *Glossopteris* flora has been noted at Yellow Cliff in the interior of the continent.

Tasmania.—In Tasmania the Wynyard glacial beds, 1,200 feet thick, are presumably the equivalents of the Talchir ; amongst the tillites themselves have been found two or three glaciated pavements. Glacial erratics are also to be observed, associated with the *Eurydesma cordatum* banks, in strata corresponding to the Lower Marine series, and are to be found also in the Upper Marine series, above the coal measures which are the equivalents of the Greta Coal Measures. These coal-bearing beds are the Mersey River Coal Measures of Lower Permian age, which have yielded three or four species of *Glossopteris*, the two most characteristic Indian species of *Gangamopteris* (*cyclopteroides* and *angustifolia*). *Cordaites Noeggerathiopsis*) *hislopi* and other forms. In the Ross Sandstones, which form the bulk of the Lower Trias, occurs the oldest known Australian reptile, one of the Captorhinidae.

Conditions in Australia.—In the opinion of David, the late Palæozoic ice of Australia originated in and radiated from a plateau southwest of Tasmania and to the southeast of Adelaide, moved over a land surface of comparatively low relief, and crossed some of the pre-existing valleys nearly at right angles.[1] Summarising, we may conclude that glaciation in Australia was on a very extensive scale. As already mentioned, cases have been observed of glacial pavements within the tillites themselves. According to David, the bands of sandstone, conglomerate and shale, which are interstratified with the tillites, exhibit proof of contemporaneous erosion, attributed to the pressure of glacier ice, to the grinding of ice-bergs or to the melting of subsequent sheets of ice and snow.[2] In Australia, as in other parts, the ice was present in the form of both land ice and floating ice. Proof of the former is seen in the pavements and *roches moutonnées*, and of the latter in the glaciated erratics and the ripple-marking on some of the intercalations in the tillites of Bacchus Marsh and Tasmania, and in the compositional variation of the groundmass of the tillite according to the composition of the subjacent rock. Evidence is to be seen here and there of the southeastern shore of the ancient Tethys Sea. The various stages of the Gondwana equivalent in Australia show the same overlap and transgression as they do in India.

New Zealand.—It is highly probable that the *Glossopteris* flora is present in New Zealand, for the fossil frond therefrom described under the name of *Linguifolium* is considered by more than one observer either to belong to the genus *Glossopteris* or to be closely related thereto.

South Africa.—In South Africa we again find the Gondwana system represented in beds of great interest and importance, attaining a maximum thickness of well over 20,000 feet, excluding volcanic rocks. A concise account of the Gondwanas of South Africa is to be found in Dr. Du Toit's manual (" The Geology of South Africa", 1st Edit. 1926 & 2nd Edit. 1939), from which much of the following information is derived. Marine fossils are completely absent except in parts of South-West Africa. In Cape Colony, Natal, the Transvaal and the Orange River Colony, the Karroo system, as it is called, consists of fluviatile or lacustrine sandstones, and shales, with interbedded seams of coal resembling that of the Damudas in its laminated structure. Occasionally an old land surface with spreading tree roots can be made out.[3] This sedimentary sequence has been invaded by sheets and dykes of dolerite, corresponding to the similar dykes in the Indian Gondwanas. More important, as we shall see, than the mineralogical resemblances are the similarities shown by the fossil floras and faunas of the two countries.

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[1] C. R. *Congr. géol. internat. Xe*, 450 (1906).

[2] *Ibid.*, 449.

[3] E. T. Mellor and T. N. Leslie. *Trans. Geol. Soc. S. Afr.*, IX, 125 (1906).

With regard to its distribution and relations to older rocks, this fresh-water formation occupies a very large tract of dry lands in the interior of South Africa drained by the head-waters of the Orange river and its southern affluents, and of the principal rivers which debouche on the south coast. Rocks of a similar character have been observed in South-West Africa, along the margin of the Kalahari desert, over parts of Rhodesia, Portuguese East Africa, and regions farther north in central Africa. Through overlap by successive stages there is a general thinning of the system in South Africa from south to north. Over the whole of the area in South Africa, the beds in general lie horizontally—except along the southern margin where the lower members have been disturbed—and give rise to large, flat, desert plains known as *karroo*, from which the system derives its name. In early Mesozoic times the greater part of South Africa was probably covered by strata belonging to one or other of the Karroo stages but, as we have suggested in the case of India, deposition is presumed to have taken place in distinct basins.

Between the Great Fish river and the St. John's river, the Karroo beds extend to the east coast ; elsewhere they are separated from it by a series of ranges formed of more or less disturbed Palæozoic strata. Among the latter the Bokkeveld beds contain a fauna of Lower to Middle Devonian facies, overlain by the plant-bearing Witteberg quartzites, containing a poorly preserved flora allied to the Lower Carboniferous or Upper Devonian of Europe. The Karroo system may be divided into the following subdivision :

Stormberg series . . .	Drakensberg Volcanic beds	Rhætic to Lias.
	Cave Sandstone . . .	
	Red Beds	Trias.
	Molteno beds . . .	
Beaufort series . . .	Upper, or Burghersdorp Beds .	
	Middle	
	Lower	
Ecca series . . .	Upper Ecca shales . . .	Permian.
	Middle Ecca Coal Measures .	
	Lower Ecca shales . .	
Dwyka series . . .	Upper Dwyka shales and " White band. "	Upper Carboniferous.
	Dwyka tillite . . .	
	Lower Dwyka shales . .	

Where the " Lower Dwyka shales " are present, they pass down without a break into the Witteberg series and are, in fact, more akin lithologically to the latter than they are to the rest of the Dwyka ; elsewhere the tillite transgresses across the rocks of the Cape system and older groups " to rest upon the Archæan while the floor beneath it becomes uneven and in good exposures reveals typically striated *roches moutonnées.*"[1] The Lower Shales are described as sediments deposited in the body of fresh-water into which the Dwyka ice-front subsequently moved and dropped its included debris.[2] As in modern examples, the "stoss" and "lee" sides of the *roches moutonnées* can in some cases be made out. There are many fine examples of striated pavements underlying the Dwyka tillite which, in parts of Natal, can be seen resting in ravines scoured in the Table Mountain Sandstone and sometimes banked against cliffs of this rock.

Represented by the boulders in the tillite, some of them of large size, is an immense variety of pre-Karroo rocks, a high proportion of them consisting of amygdaloidal diabase, a rock from which also much of the matrix has been derived. Many of the boulders are striated and facetted and the majority, especially in the south, are characterised by a regular and close jointing. In rare instances only are there signs of stratification in the glacial material which for the most part is obviously a ground moraine. Some of the shaly beds above the tillite or occupying pockets therein are ripple-marked but, except in South-West Africa marine fossils are absent from the Dwyka, as indeed from all other subdivisions of the Karroo system. The Dwyka boulder beds are thickest in the south and thin out towards the north ; beyond latitude 27°S. the outcrops of the Dwyka series become insignificant and erratic. There can be no doubt that the basal stage of the Dwykas resting in several places on smoothed and deeply furrowed pavements of older rocks, and composed of blocks of various sizes embedded in a fine-grained matrix precisely similar to that of the Talchirs, was formed during the same cold period which has left such conspicuous traces in India and Australia. In South Africa the ice sheets all seem to have moved with a southerly tendency and to have radiated from a plateau occupying what are now the Transvaal, Rhodesia and Orange River Colony.

The Lower Shales have yielded fishes, *Cyclodendron* and a doubtful *Phyllotheca.* Although the tillite, as would be expected, is barren of organic remains, impressions of *Gangamopteris cyclopteroides* have been noted in two localities between the base of that deposit and the underlying platform of pre-Devonian rocks.[3] From the Upper Shales have been obtained *Lepidodendron australe* McCoy and a species of *Dadoxylon ;* their marine phase in South-West Africa is marked by the presence of the thick-shelled lamellibranch, *Eurydesma globosum* Dana, another lamellibranch, *Aphanaia haibensis* Reed, a species of *Orthoceras,* the gastropod *Conularia,* and the fishes, *Acrolepis lotzi* Gürich, and *Namaichthys schrœderi* Gürich. These shales pass up into the "White Band", a zone of white-weathering, carbonaceous and pyritic shales, with occasional casts of three species of the small aquatic reptile, *Mesosaurus,* a genus found elsewhere only in the Iraty shales of southern Brazil, remains of the crustaceans, *Notocaris* (*Pygocephalus*) *tapscotti* Broom and *Anthrapalœmon* sp., the fish *Palœoniscus capenste* Broom, and a species of *Glossopteris.* The "White Band" is an important connecting link between South Africa and South America.

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[1] A.L. Du Toit, "A Geological Comparison of South America with South Africa", *Carneg. Inst. Wash.*, 8 (1927). *Brit. Ass.*, p. 209 (1929) : Du Toit, "Geology of South Africa," 2nd. Edit., 247 (1939).

[2] A.L. Du Toit, "Geology of South Africa", 2nd. Edit., 315-316 (1939)

[3] A. L. Du Toit, "Geology of South Africa", 2nd Edit., p. 239 (1939).

With regard to the age of the Dwyka, the Witteberg series down into which it passes, is considered, so far as a badly preserved flora and relics of an eurypterid (*Hastimima*) can be trusted, to cover the time interval from about Middle Devonian to Middle Carboniferous. The scanty fossils in the Dwyka series are believed to indicate an Upper Carboniferous horizon, a conclusion which is confirmed by the admixture of *Lepidodendron*, *Sigillaria* and *Psygmophyllum* with *Glossopteris* and *Gangamopteris*, found in the overlying coal measures in the Transvaal and Natal.

In the southern Karroo, the White Band passes up into the Ecca series which has yielded silicified wood and the *Glossopteris* flora mingled with "northern forms", an admixture the significance of which will appear later on ; the Ecca flora comprises :

Equisetales—

- *Phyllotheca zeilleri* Eth.

Lycopodiales—

- *Cyclodendron leslii* (Sew.),
- *Lepidodendron pedroanum* (Carr.),
- ,, *vereenigingense* Sew.,
- *Sigillaria brardi* Brongn.,
- *Stigmaria ficoides* Brongn.

Pteridospermae & Filicales—

- *Gangamopteris cyclopteroides* Feistm.,
- ,, *kashmirensis* Sew.,
- *Glossopteris browniana* Brongn.,
- ,, *indica* Schimp.,
- ,, *brancai* Gothan.,
- ,, *retifera* Feistm.,
- ,, *stricta* Bunb.,
- ,, *tortuosa* Zeill.,
- *Vertebraria indica* Royle.

Cordaitales—

- *Gondwanidium* (*Neuropteridium*) *validum* (Feistm.),
- *Cordaites* (*Noeggerathiopsis*) *hislopi* (Bunb.),
- *Sphenopteris* sp.

Sphenophyllales—

- *Sphenophyllum oblongifolium* Germ.,
- ,, *speciosum* (Royle.),
- ,, *thonii* Mahr.,
- *Asterotheca* sp.
- *Pecopteris arborescens* Schloth.,
- ,, cf. *cyathea* Schloth.,
- ,, *hemiteliodes* Brongn.,
- ,, *unita* Brongn.

Coniferales—
- *Abietopitys perforata* Kräusel.,
- *Dadoxylon porosum* Kräusel.,
- ,, *rangei* Kräusel.,
- ,, *arberi* Sew.,
- *Medullopitys sclerotica* Kräusel.,
- *Phyllocladopitys capensis* Kräusel.,
- *Taxopitys africana* Kräusel.,
- *Conites* sp.,
- *Samaropsis leslii* Sew.,
- *Cardiocarpus* sp.

Incertæ Sedis—
- *Psygmophyllum kidstoni* Sew.,
- *Ottokaria leslii* Thomas.

Elsewhere the facies varies and in some parts is closely comparable with the second and third stages of the Paganzo system of western Argentina, and has resemblances to the Estrada Nova formation of Uruguay. In New South Wales the equivalents are the upper portion of the Lower Marine series, the Greta Coal Measures and the Upper Marine series. The Transvaal and Natal Coal Measures are a fluviatile and thinner phase of the Ecca.

The bulk of the Ecca sediments, among which are many local unconformities and " washouts," appears to have been transported from land lying far to the south, the finer material for that reason having been carried farther north. With a maximum thickness of over 6,000 feet, the Ecca series has the following features in common with the Damuda : beds of coal, beds of clay ironstone, calcareous concretions, the sandy and micaceous nature of the shales, and other minor resemblances. Some at least of the Ecca coal, however, seems to have been formed from the growth of vegetation *in situ*, and fossil forests have been exposed at Vereeniging.

The following is a list of forms from the Beaufort series, abstracted from Dr. Du Toit's list (pp. 316-317) :—

UPPER BEAUFORT (BURGHERSDORP BEDS).

Equisetales—
- *Schizoneura* sp.

Pteridospermæ and Filicales—
- *Neocalamites (Schizoneura) carrerei* (Zeill.),
- *Thinnfeldia odontopteroides* (Morr.),
- ,, *lancifolia* (Morr.),
- ,, *feistmanteli* John.,
- ,, *acuta* Walk.,
- *Danæopsis (? Thinnfeldia) hughesi* Feistm.,
- *Odontopteris browni* Sew.,
- *Callipteridium africanum* du Toit.,
- *Glossopteris browniana* Brongn.

Cycadophyta—
- *Tæniopteris nilssonioides* Zeill.,
- ,, *lata* Oldh.,
- ,, *magnifolia* (Font.).
- *Pterophyllum* cf. *tietzei* Schenk,
- *Nilssonia browni* du Toit.

Coniferales—
    Strobilites laxus Sew.,
    Stigmatodendron dubium Sew.
Ginkgoales—
    Ginkgoites magnifolia (Font.).

MIDDLE BEAUFORT.

Epuisetales—
    Schizoneura (fragments).
Pteridospermæ—
    Glossopteris browniana Brongn.,
    ,, ,, var. *angustifolia* Brongn.

LOWER BEAUFORT.

Equisetales—
    Phyllotheca zeilleri Eth.,
    ,, *australis* Brongn.,
    Schizoneura africana Feistm.,
    ,, *gondwanensis* Feistm.
Pteridospermæ—
    Glossopteris browniana Brongn.,
    ,, ,, , var. *indica* Schimp.,
    ,, ,, , var. *angustifolia* Brongn.,
    ,, *ampla* Dana,
    ,, *retifera* Feistm.,
    ,, *conspicua* Feistm.,
    ,, *cordata* Feistm.,
    ,, *stricta* Bunb,
    Vertebraria indica Royle,
    Sphenopteris alata (Brongn.).
Sphenophyllales—
    Sphenophyllum speciosum (Royle).
Cycadophyta—
    Tæniopteris (*Angiopteridium*) *spatulata* (McClell.).
Coniferales—
    Dadoxylon arberi Sew.,
    Spiroxylon africanum Walton,
    Eretmonia natalensis du Toit.

While *Glossopteris* has survived, *Gangamopteris* has not; accompanying the plants in the Lower stage are the fresh-water mollusca, *Palæomutela* (*Archanodon*) and *Palæanodonta*—two genera the occurrence of which derives its interest from the fact that they are found in the "Reptile Beds" of Russia—and a few fish remains. Out of nine species of *Palæomutela* identified by Amalitsky, no less than four, and possibly five, were found to be Russian forms; both the species of *Palæanodonta* recognised by this observer also occur in Russia.[1] Three additional Russian species of *Palæomutela* have been recognised by L. R. Cox from the Lower Beaufort beds of Tanganyika.[2] Better known than the plants are the numerous reptilian remains, chiefly from the south, which have made the Beaufort beds famous. These too show a distinct connection with the much more limited Lower Gondwana fauna. The labyrinthodont, *Brachyops laticeps* Owen, from the Mangli beds of India is closely related to *Micropholis stowi* Huxl., from the Beaufort beds. In the Lower stage, no less than 77 genera of reptiles are quoted by Dr. Du Toit, the most important being the massive *Pareiasaurus, Propappus* and *Tapinocephalus*, the sharp-toothed *Titanosuchus*, the Dicynodons and the massive-jawed *Endothiodon ;* some of these have closely allied forms in the Permian of north Russia. In addition, in the upper horizons of the stage, are reptiles with pointed skulls and sharp canines such as *Scymnosaurus, Lycosuchus, Cynodraco*, and the large amphibian *Rhinesuchus*. In the Middle stage, nearly all the reptiles belong to *Lystrosaurus*, a genus represented in the Indian Panchet. The tiny crustacean, *Estheria* [*Cyzicus*], is to be occasionally found. In the Upper or Burghersdorp stage, the reptiles comprise the large dicynodont *Kannemeyeria*, the grotesque *Erythrosuchus* closely allied to the Brazilian *Scaphonyx*, several cynodonts such as *Cynognathus, Gomphognathus* and the small *Ictidopsis*. The amphibians are interesting in that they include genera characteristic of the Trias of central Europe and, unlike the reptiles, therefore, bear witness to an incursion of northern forms. The most important are *Trematosaurus, Cyclotosaurus*, and *Capitosaurus ; Batrachosuchus* belongs to a family represented only in India and Australia. Plants are scarce in the Upper stage of the Beauforts, the commonest being *Schizoneura* ; from the top come *Danæopsis, Pterophyllum, Thinnfeldia* and *Ginkgoites*, the two last (and possibly the first) presaging the advent of the *Thinnfeldia* flora and characterising the overlying Molteno beds.

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[1] *Q. J. G. S.*, LI, 338 (1895).

[2] *Q. J. G. S.*, LXXXVIII, 625 (1932).

The Beaufort beds are more sandy than the Ecca and resemble lithologically the Panchets of India. There are many local unconformities, and the conditions of deposition suggested are those of vast flats subject to periodical flooding, the temporary drainage channels of which have been recorded as "washouts". There are a few thin coal seams in the Beaufort series.

The Indian Damuda series is probably the equivalent of the Ecca *plus* the Lower Beaufort, the Ecca corresponding to the Karharbari and Barakar (and Ironstone Shales where present), and the Lower Beaufort to the Raniganj, which is probably represented in New South Wales by the Newcastle series (see Table pp.1097-8 The Panchet series of India may be considered as the equivalent of the Middle and Upper Beaufort series with the addition of the overlying Molteno beds, and perhaps also of the Red Beds ; the Molteno is a series which has a flora markedly resembling that of the Ipswich beds of Queensland and that of the Cacheuta beds in Argentina. The Indian Parsora stage would also equate either with the Upper Beaufort or with the Molteno, while the Tiki and Maleri beds appear to be the Indian representatives of the Cave Sandstone. The Trias of Europe has been equated with the Middle and Upper Beaufort together with the Molteno and the Red Beds. From the Molteno, which is largely a deltaic deposit, the following plant remains have been collected and belong to a flora not so different from that of the Lower Karroo as the Upper Gondwana flora of India is from that of the Lower Gondwana :

Equisetales—

Neocalamites ("*Schizoneura*") *carrerei* (Zeill.).

Pteridospermae and Filicales—

Thinnfeldia odontopteroides (Morr.),
,, *lancifolia* (Morr.),
,, *feistmanteli* John,
,, *acuta* Walk.,
,, *narrabeenensis* Dun (M. S.),

Pterophyllum inconstans (Braun.),
,, *multilineatum* Gepp.,

Pseudoctenis capensis du Toit,
,, *carteriana* (Oldh.),
,, *lanciformis* du Toit,
,, *spatulata* du Toit,

Tæniopteris carruthersi Ten.-Woods,
,, *brackebuschiana* Kurtz,
,, *crassinervis* (Feistm.),
,, *(Angiopteridium) spatulata* Mc Clell.

Cycadophyta—

Callipteridium africanum du Toit,
,, *stormbergense* Sew.,
Cladophlebis nebbensis Brongn.,
,, *(Todites) göppertiana* (Schenk),
,, ,, *rösserti* (Presl.),

Chiropteris copiapensis Solms,
,, *cuneata* (Carr),
,, *zeilleri* Sew.,
Pachypteris acuta du Toit,
,, *incisa* du Toit,
Stenopteris elongata (Carr),
,, *densifolia* du Toit,
Lepidopteris natalensis Thomas,
Stormbergia gardneri Sew.,
Sphenopteris lobifolia Morr.,
Glossopteris browniana Brongn.,
,, *conspicua* Feistm.,
Johnstonia coriacea Walk.

Cordaitales—

Dadoxylon sclerosum Walt.,
Pteruchus sp. (fructification),
Umkomasia sp. (fructification.),

Ginkgoales—

Ginkgoites antarctica (Sap.),
,, *digitata* (Brongn.)
,, *magnifolia* (Font.),
,, *moltenensis* (Sew.),
Baiera schenki Feistm.,
,, *tenuifolia* John,
Phœnicopsis elongata (Morr.),
Moltenia dentata du Toit.

Incertae Sedis—

Rhexoxylon africanum Bancr. (a unique genus of fossil wood, constituting a valuable link between South Africa and Antarctica during Triassic times),
,, *priestlyi* (Sew.),
,, *tetrapterioides* Walt.

This flora, the chief members of which are *Thinnfeldia*, *Tæniopteris*, *Baiera*, *Ginkgoites*, *Callipteridium*, *Schizoneura*, *Stenopteris* and *Phœnicopsis*, is very different from the assemblages in the Lower Karroo, in spite of the persistence of *Glossopteris*. Trunks of *Dadoxylon* are abundant in the Molteno, seams of coal are occasionally found, but vertebrate remains are practically absent.

Fossil wood, including *Rhexoxylon africanum* and possibly *Dadoxylon sclerosum*, is abundant in the Red Beds, which have also yielded a *Schizoneura* stem and several important vertebrate remains, principally dinosaurs such as *Thecodontosaurus*, *Massospondylus*, *Euskelesaurus*, *Plateosaurus*, and *Gryponyx*, an assemblage indicating a Triassic age ; to these must be added the teeth of the fish, *Ceratodus*, *kannemeyeria* Seeley, and remains of the crustacean, *Estheria*. The Somabula beds of Rhodesia, the approximate equivalents of the Red Beds, have yielded : *Thinnfeldia odontopteroides*, *T. lancifolia*, *T. feistmanteli*, *Tæniopteris macclellandi*, *Schizoneura gondwanensis*, *Rhexoxylon africanum* and *Dadoxylon* sp.

The Cave Sandstone is described as being extraordinarily massive, and is thought to be primarily eolian in origin. Reptiles persist into the Cave Sandstone but are scarce, among them being *Thecodontosaurus* and *Notochampsa*. Other fossils are the Keuper fish, *Semionotus capensis*, and the two phyllopods, *Estheria*]*Cyzicus*] *draperi* Jones & Woodw., and *Lepidurus stormbergensis* Haughton, of which the former species is found in the Rhætic of Argentina and is similar to *E. mangaliensis* in India. According to Dr. Du Toit, the Cave Sandstone cannot be younger than Rhætic.

The Drakensberg Volcanic beds, a succession principally of basic lavas with a maximum thickness of about 4,500 feet, form the extensive and deeply dissected mass of Basutoland. The majority of the rocks consist of basalt, either compact or amygdaloidal and zeolitic, but tuffs and agglomerates are in places found near the base and are thought to be the outcome of eruptions of the central type. The remains of many volcanic necks have been exposed, the best known being that of Modderfontein, but the bulk of the effusions, like those of the Deccan Trap, seem to have been of the fissure variety and to have poured out a highly mobile lava. The Drakensberg series may be of Liassic age but eruptions really commenced before the end of the Cave Sandstone epoch. Though much earlier in age, the Drakensberg Volcanics appear to be the petrological equivalents of the Deccan Trap and play a similar role in the physiography of the country.

Very intimately related to the Drakensberg Volcanics are the Karroo Dolerites. These are basic intrusions in the form of sheets and dykes mostly of dolerite but sometimes of diorite, gabbro, norite and occasionally picrite, which have penetrated the various stages of the Karroo system and are especially numerous in the lower subdivisions thereof. Boulders of dolerite are found in Lower Cretaceous conglomerates and, judging from the close association with the Drakensberg basalts, the intrusions date probably from the commencement of the Jurassic period. They may, therefore, have commenced earlier than the dolerites of the Indian coalfields, but the parallelism in the two regions is otherwise undeniable.

Assigning the Drakensberg series to the Lias, we find the rest of the Jurassic unrepresented and the Lower Cretaceous present in the form of the Uitenhage series with its somewhat scanty flora.

In the neighbourhood of Algoa Bay, a set of fossiliferous shales and sandstones, known as the Uitenhage series, of no great thickness and restricted in occurrence to the vicinity of the coast, bears much the same relation to the Karroo system of the interior as do the littoral outliers of the Coromandel Coast Upper Gondwanas to the Lower Gondwanas of the interior of the Indian peninsula. Like the sediments of the Indian coast, the African beds are in part of marine origin and have yielded marine fossils which have been shown to be Lower Cretaceous in age (Neocomian or, in the case of the Indian beds, either Neocomian or Barremian). The plant remains from the Uitenhage series include :[1]

Filicales—
  Osmundites kolbei Sew.,
  Cladophlebis denticulata (Brongn.),
      ,, *browniana* (Dunk.),
  Onychiopsis mantelli (Brongn.),
  Sphenopteris fittoni Sew.

Cycadophyta—
  Tæniopteris sp.,
  Zamiites recta (Tate),
      ,, *morrisi* (Tate),
      ,, *africana* (Tate),
      ,, (*Pseudoctenis*) *rubidgei* (Tate),
  Nilssonia tatei Sew.,
  Bucklandia cf. *anomala* (Stokes & Webb),
  Otozamites sp.,
  Dictyozamites sp.,
  Cycadolepis jenkinsiana (Tate).

Coniferales—
  Araucarites rogersi Sew.,
  Brachyphyllum sp.,
  Conites spp. Sew.,
  Benstedtia sp., cf. *Coniferocaulon colymbioëforme* Flich,
  Taxites sp.,
  Coniferous wood.

Incertae sedis—
  Carpolithes sp.

Away from the coast in some places fresh-water shells such as *Viviparus*, *Unio* and possibly *Cyrena*, have been identified. Among the numerous marine fossils found in the Uitenhage beds are species of the ammonite *Rogersites* (*Holcostephanus*) which find their closest European equivalents among Upper Valanginian (Middle Neocomian) forms. *Trigonia ventricosa*, a lamellibranch characteristic of the Umia beds of Cutch, is among the Uitenhage assemblage. Full lists of the Uitenhage fauna will be found in Dr. Du Toit's "Geology of South Africa."

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[1] Seward. *Ann. S. Afr. Mus.*, IV, Pt.I (1903).

Tropical Africa.—The *Glossopteris* flora has been recognised in Portuguese East Africa in beds belonging probably to the Ecca series, and has left traces in Zululand and the region of Lake Nyasa. Members of the Karroo system have been recognised in both Southern and Northern Rhodesia, the oldest containing *Glossopteris* and silicified wood; coal seams form part of the sequence, the highest portions of which are correlated tentatively with the Stormberg series. North of the Zambesi occurs a succession of basaltic lavas regarded as of Upper Karroo age. The *Glossopteris* flora has been found in the southeastern and eastern parts of the Belgian Congo State and in the British Protectorate of Uganda; in the former area glacial beds equivalent to the Dwyka have also been observed. The occurrence in Uganda is from Entebbe on the margin of Lake Victoria Nyanza and comprises: *Gangamopteris cyclopteroides*, var. *attenuata* Feistm., *Glossopteris indica* Feistm., *Cyclodendron leslii* Sew., *Psygmophyllum* sp., *Cordaites* (*Noeggerathiopsis*) sp. and *Cornucarpus* sp.[1] From the basin of the Luena in the Katanga Province of the Belgian State have been obtained *Vertebraria* sp., *Phyllotheca* sp., *Glossopteris indica*, *G. browniana* and *Cordaites* (*Nœggerathiopsis*) *hislopi*, forming apparently part of an Ecca flora.[2] The valley of the Lukuga has yielded: *Stenopteris elongata*, *Fusigillaria favularia*, *Subsigillaria leiodermaria*, *Cordaites* (*Nœggerathiopsis*) *hislopi*, *Schizoneura* sp., *Glossopteris indica*, *Nummulospermum* sp., *Phyllotheca zeilleri* and *Cyclodendron leslii*—an assemblage assigned to the middle portion of the Ecca series.[3] From the region of Walikale, northwest of Lake Kivu, further representatives of the Ecca series have been observed, the oldest members perhaps reaching down into the Dwyka; *Glossopteris* is here absent and *Gangamopteris cyclopteroides* is the dominating form, other forms being *Cyclodendron* sp., *Gangamopteris cyclopteroides*, var. *attenuata*, *Samaropsis* Göepp. or (?) *Cordaicarpus* Gein., or *Nummulospermum* Walk. or *Cornucarpus* (Arber), *Voltzia* sp., *Cordaites* (*Nœggerathiopsis*) *hislopi*, and a form comparable to *Phyllotheca*.[4] Traces of the *Glossopteris* flora have also been found 20 kilometres south of Albertsville on the banks of Lake Tanganyika. From the Karroo formation in the Upper Gombati river just below Mt. Lukenzi, Tanganyika Territory, have been collected *Glossopteris conspicua*, *G. indica* and an equisetaceous stem.[5] From beds of Lower Beaufort (Upper Permian) age in the Ruhuhu coalfields of Tanganyika, east of Lake Nyasa, come some of the small fresh-water lamellibranchs belonging to the genus *Palæomutela* and very abundant in certain of the beds; Dr. L. R. Cox finds that three of the five species are Russian forms.[6] Traces of the Lower Gondwana ice age have been recorded in Togo Land on the Slave Coast, Gulf of Guinea.

Madagascar.—In western Madagascar there has been noted a succession consisting of a basal boulder conglomerate made up of angular crystalline blocks, often of large size, scattered in a clayey or sandy paste, accompanied by coal-bearing strata (Sakoa beds) with *Gangamopteris major*, *G. cyclopteroides*, *Glossopteris* sp. and *Schizoneura* sp.[7]

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[1] A. L. du Toit. *Ann. S. Afr. Mus.* XXVIII, 395-406 (1932); see also *Geol. Mag.*, LXXI, 385 (1924).

[2] *Bull. Acad. Roy. Belg.*, Ser. V, XIX, 561 (1933).

[3] *Ibid.*, Ser. V, XV, 635 (1929).

[4] *Bull. Soc. Belg. de Géol.*, Vol. XLIII, 65 (1933-34).

[5] L. S. Robertson. *Q. J. G. S.*, XC, 1—6 (1934).

[6] *Ibid.*, LXXXVIII, 623 (1932).

[7] Paul Range. *C. R. Congr. Géol. internat.* XVe., 116 (1929)

The Sakamena series, which lies upon these beds with a clear discordance and overlap marked by a conglomerate, contains several species of the *Glossopteris* flora (*G. indica*, *Schizoneura* cf. *gondwanensis*, *Cordaites* (*Nœggerathiopsis*) cf. *lacerata*, *Cladophlebis remota*, *Danæopsis* sp., *Tæniopteris* sp., *Voltzia* sp. and *Lepidopteris* sp.), and reptiles such as *Atherstonia*, *Tangasaurus*, *Cœlurosaurus* and *Rhinesuchus*, but also intercalations of beds with marine fossils ; among the latter, at various horizons, are : *Productus* cf. *curvirostris* Schellw., *Spirifer* cf. *rectangulus* Kut., *Avicula* sp., *Scaldia* sp., *Soleniscus* sp., *Loxonema* sp., *Myalina* sp., *Syringopora* sp., ? *Anthracoporella* sp., *Cyclolobus walkeri* Dien., *Episageceras* (*Medlicottia*) *wynnei* (Waag.), *Xenaspis carbonaria* Waag., *Hungarites* sp. and the fish, *Allorisma*—members of a Permian fauna.

The Beaufort series is also represented by beds containing small reptiles amphibians and fishes, the reptiles apparently allied to the South African genus *Saurosternon*, and agreeing with some European species ; with one of the reptile skeletons a leaf impression of *Glossopteris indica* has been found associated.

South America.—An able review of our knowledge of the Gondwanas of South America will be found in Du Toit's "Geological Comparison of South America with South Africa".[1] In southern Brazil and the adjoining parts of Uruguay and Paraguay, the Santa Catarina system, which is the equivalent of the Gondwana, covers an area of something like 386,000 square miles and is therefore comparable in size with the Karroo basin of South Africa. The great bulk of its outcrop forms a broad and very flat geological basin occupying the valleys of the Parana and Uruguay rivers, the greater part of the exposure consisting of a volcanic group at the top of the sequence. The system is tentatively classified as follows :—

Sao Bento series	Serra Geral eruptives	Rhætic-Liassic.
	Botucatú Sandstone (where separable).	Triassic.
	Río do Rasto stage	
Passa Dois series	Estrada Nova—upper part	
	....	
	Estrada Nova—lower part	Permian.
	Iraty stage and Melo beds	Upper Carboniferous.
Tuberão series	Palermo stage	
	Bonito stage	
Itararé Glacial beds		

The Itararé, Tuberão and Iratý formations correspond to the Talchir of India, and to the Tillite and Upper Shales of the Dwyka series in South Africa. The Estrada Nova represents the Damuda (including the Karharbari) and probably the lower part of the Panchet, while the Río do Rasto and Botucatú beds appear to be on a level with the higher Panchet.

The Itararé series comprises beds of glacial origin in every way similar to those found in Australia, South Africa and India, alternating with sediments indistinguishable from the conglomerates, grits, sandstones and shales of the succeeding Bonito stage or Coal Measures. In places the Itararé series reaches a thickness of nearly 1,000 metres (3,280 feet) but, as in the case of its equivalents elsewhere, much of the succession is not glacial. The glacial beds vary from a true ground moraine to a bedded shale with small inclusions of fluvio-glacial sandstones, some of them current-bedded and some of them with waterworn pebbles. Most of the boulders in the tillite are of small size, but one granite erratic is recorded measuring fully 18 cubic metres (636 cubic feet).

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[1] *Carneg. Inst. Wash.*, 8 (1927).

In some places the floor of ancient rocks on which the glacial beds lie is comparatively even; in others it is uneven. In northeast Uruguay, as Dr. Du Toit points out, there can be no doubt as to the highly diversified character of the pre-glacial surface. Knobs of the crystalline floor are described as projecting through the gently dipping Gondwanas and are in some cases surrounded by stages as young as the Estrada Nova. " The conspicuous Cuchilla de Cerro Largo has the appearance of being a glaciated range that must have remained exposed long after the ice had disappeared and its undulating base had become buried beneath glacial, fluvio-glacial and normal sediments."

Dr. Oliveira records a bed of marine fossils sandwiched between two banks of boulder shales in the upper part of the Itararé, a proof that at this stage and in this locality the ice was being discharged into the ocean.

In the Tuberão valley, the Itararé is reduced to about 32 metres (105 feet), the bulk of which is formed of the well known and probably local massive " Orleans Conglomerate".

In the exposure to the northeast of Montevideo the succession resembles that of San Juan in Argentina. Here there are three separate glacial horizons, each of them, however, separated from the rest by a small thickness only of normal sediment; the highest is thin and contains erratics, some of which are striated. The uneven floor is made up of low ridges and hollows, the coarser glacial material arching over the former and dipping at comparatively high angles towards the finer tillite filling the hollows; in places the tillite is seen tucked in beneath the low ridges and at one spot is banked against a vertical wall of limestone and crammed with fragments of that rock. In most cases the hollows follow the direction of glaciation, and there are indications that the ice came from the southeast, *i.e.*, from somewhere in the present Atlantic.

The Bonito shales, which in places overlap the Itararé beds on to the granite floor, are frequently plant bearing, and include seams of workable coal. In the lower levels, from almost immediately above the Orleans Conglomerate, several members of the *Glossopteris* flora are present, including such types as *Glossopteris browniana*, *Gangamopteris cyclopteroides*, *Cordaites hislopi*, *Phyllotheca griesbachi* and *P. muelleriana;* in the higher levels this flora is associated with " northern forms", an admixture to which reference will be made later on, and we find *Lepidodnedron*, *Sigillaria* and *Lepidophloios* side by side with *Glossopteris indica. G. ampla* and *G. occidentalis.*

The Palermo stage, in which silicified wood in the form of *Dadoxylon* is common, passes up without a break into the Iratý shales.

The Iratý stage, with its carbonaceous and often papery shales, bleaching to paler colours, has much in common with the Talchir shales or the " White Band " of the Dwyka shales. In it are frequent and widespread remains of the small reptile, *Mesosaurus*, and the larger form, *Stereosternum*, if generically distinct; *Mesosaurus tumidus* and *Stereosternum* (? *Mesosaurus*) *brasiliense* are closely akin to the *Mesosaurus tenuidens* of South Africa. Du Toit remarks that "the exclusive presence of *Mesosaurus* and the outstanding lithogical similarities, down to minuitæ, render the correlation of the Iratý group with the White Band of the Dwyka series absolutley assured, although a distance of 6,300 km. (3,915 miles) separates the two". This fact is interesting in its favourable bearing on the theory of continental drift.

The Estrada Nova which, like the Iratý, is extremely constant throughout the Parana-Uruguay basin, follows the latter stage with seeming conformity. Its fauna indicates an estuary occasionally invaded by the sea, while its flora includes *Glossopteris* and other forms found near the top of the formation. The Estrada Nova probably consists of two distinct groups with an unconformity and time gap between them representing the uppermost Permian and much of the Lower Trias.

The sedimentary part of the São Bento series is predominantly eolian in origin as indicated by the well rounded sand-grains of the arenaceous deposits. In the Río do Rasto stage have been found an abundance of silicified wood—probably *Dadoxylon*—a *Cladophlebis*, and a few dinosaur remains including *Scaphonyx fischeri*, a form allied to *Euskelesaurus* from the Upper Triassic Red Beds of South Africa, and a specis of *Erythrosuchus* comparable to *E. africanus* from the Upper Beaufort stage of the same country. The Río do Rasto, at least 1,300 feet at its thickest, is described as being extraordinarily like the Cave Sandstone and Red Beds of Basutoland and Southern Rhodesia.

The traps of the Serra Geral, basaltic to andesitic in composition, are comparable with the Stormberg basalts and, like those in the western Argentine and Patagonia, are Rhæto-Liassic in age. In the lower part of the stage in one area are seen sedimentary intercalations, from one of which tiny "dreikanters" have been obtained.

The resemblances to South Africa are completed by the sheets and dykes of basic rock, mostly dolerite, which penetrate the members of the Santa Catarina system, more especially those forming its lower half. As in South Africa, the intrusions are suspected to have taken place just after the eruptions and to be Jurassic in age.

In the northeast of Brazil is another exposure of Gondwanas, among which the glacial beds have not been recognised. Here the Paranahyba series corresponds more or less to the Passa Dois, while the succeeding Mearim series, with its upper portion of basic lavas, is very like the São Bento of the south.

Gondwanas of a more disturbed type are probably present in the coastal region of Bahia and Sergipe in eastern Brazil.

To the north of Bahia Blanca in the Argentine, the Gondwanas have been folded and metamorphosed. Here the tillite is cleaved and passes up into quartzites and slaty beds which are the equivalents of the folded Ecca beds in the southwestern part of Cape Colony and of the Lafonian of the Falkland Islands. The glacial stage consists not entirely of morainic material; scored pavements have been noted within some of the tillite, the moraine apparently having itself been over-ridden by the ice.

Along the eastern flank of the Andes in the west of Argentina, stretching from San Rafael for some distance northwards across the border into Bolivia, is a series of outcrops of rocks belonging to the Gondwana, here known as the Paganzo system, and resting unconformably upon Lower Palæozoic or crystalline rocks. The basal beds of the Paganzo system are considered to be the equivalents of the Itararé beds of Brazil and Uruguay. In one place a thickness of about 1,000 feet has been measured, but neither in western nor central Argentina have the Iratý and Estrada Nova series yet been recognised. The rocks of the Paganzo system have been involved in the Andine movement. Three separate glacial horizons have been distinguished, one at the very base of the system; between this and the next highest are some 500 feet of ordinary sediment, and between the second and third about 160 feet of similar material. Some fine boulder pavements have been noted among the tillites and the basal one lies on a highly diversified floor. The sediments between the lowest and next highest glacial beds have yielded plant remains including *Rhacopteris* and *Cardiopteris*, but no marine fossils. A *Glossopteris* flora is very closely associated with this *Rhacopteris* flora and probably intermingled therewith, though this is not yet definitely proved, and both assemblages are intimately associated with the glacial deposits. We also have *Phyllotheca, Schizoneura, Neuropteridium, Glossopteris, Gangamopteris* and *Cordaites*, occurring in the same set of beds as *Lepidodendron, Lepidophloios* and *Sigillaria*; this association of northern and southern forms is seen in the lowest stage of the Paganzo, and therefore at a lower level than it is in Brazil, and at a still lower level than that observed in South Africa (Ecca). Higher up, marine fossils, though absent from the true tillites, occur in mudstones associated with glacial erratics. From the marine fauna, as determined by Professor Cowper Reed, the age of the glacial beds should be close to the borderline between the Moscovian and the Uralian. We have definite proof in Argentina, therefore, that *Gangamopteris cyclopteroides, Glossopteris browniana* and *Cordaites hislopi* extend back well into the Carboniferous, as they do also in New South Wales, and that glaciation commenced probably before the beginning of the Upper Carboniferous. Contemporaneous basalt flows are found in the middle portions of the system. The upper portions, with a *Thinnfeldia* flora, belong to the Rhætic-Lias, while Cretaceous horizons are present in the province of Santa Cruz.

The Rhætic of La Ternera in Chile corresponds to part of the Upper Gondwana.

The Falkland Islands.—Stratigraphically and structurally, Du Toit considers that the Falkland Islands have closer relationships with the southwest of Cape Colony than they have with Patagonia. In any case they form a close link between the continents of Africa and South America. In these islands the Gondwana is represented by the Lafonian system, possibly 10,000 or 11,000 feet or more in thickness, containing four or five Indian species of *Glossopteris*—*G. indica*, *G. indica* cf. var. *wilsoni*, *G. indica* cf. var. *decipiens*, *G. damudica*, *Gl. browniana*, and *G. angustifolia*—*Gangamopteris cyclopteroides*, var. *major*, *Voltzia heterophylla*, *Desmiophyllum* sp., and several species of *Phyllotheca* and *Dadoxylon* including *Phyllotheca deliquescens* (Göepp.) (which is possibly identical with *P. australis*), *Dadoxylon bakeri* Sew. & Walt., *D. lafoniense* Halle, and *D.* cf. *angustum* Felix. The higher beds have yielded *Neocalamites* (" *Schizoneura* ") *carrerei* (Zeill.) and may belong to the Trias, but the rest of the assemblage indicates a Damuda or Permian age.[1] At the base of the system is the ubiquitous tillite with its striated boulders and facetted pebbles, identical in character with the Dwyka and Talchir, usually folded and cleaved, lying on what in places appear to be glaciated quartzite surfaces.

Antarctica.—Perhaps the most interesting discovery of all is that of Gondwana equivalents on two opposite sides of the Antarctic continent, *viz.*, in Land which fronts the southern extremity of South America, and in South Victoria Land lying in longitudes approximating those of Tasmania and the southerly bulge of Australia. From a fossil band near the top of the Beacon Sandstone in the latter area, Captain Scott's ill-fated second Antarctic Expedition collected specimens of *Glossopteris indica, G. indica*, var. *wilsoni* Sew., and *Vertebraria* sp.[2] The Beacon Sandstone of this region at the same time yielded *Rhexoxylon* ("*Antarcticoxylon*") *priestleyi* Sew., and the doubtful *Pityosporites antarcticus* (which may be badly preserved stone cells) *Glossopteris indica* and some fossil wood which is either *Dadoxylon* or perhaps *Rhexoxylon priestleyi* have been identified from the Ferrar Glacier of these parts. The precise age of the Beacon Sandstone with its coal seams is unknown, but *Rhexoxylon* is a widely distributed plant in the Trias of Gondwanaland, the anatomical complexity of its stem resembling that of certain dicotyledons; the genus is found in the Molteno beds of Cape Colony and in beds of Stormberg age in Rhodesia. Although the lower part may extend down into the Upper Carboniferous and the upper part perhaps to some extent upward into the Trias, the bulk of the formation must belong to the Damuda or Permian. The Beacon Sandstone, which is almost horizontal in South Victoria Land, stretches from Mount Nansen and the Priestley Glacier southwards for at least 700 miles to Buckley Island and Mt. Darwin in south latitude 85°, where it consists of a basal sequence of 700 feet of sandstone with large waterworn pebbles in the lower beds, succeeded by 300 feet of the same material interbedded with shale and several seams of coal, and 500 feet of sandstone at the top—1,500 feet in all. The roundness of the sandstone grains points to sand storms in a dry climate, a conclusion supported more or less by the presence of sun cracks; ripple marks are recorded in some of the beds. The narrow bands of coal interbedded with shale, on the other hand, although composed of the débris of drifted vegetation, witness to humid interludes and a marshy topography in the neighbourhood. The greater part of the Beacon Sandstone seems to have been derived from granites and gneisses exposed to the action of wind-blown sand in a climate sufficiently mild to permit of the existence of *Glossopteris* and its fellows, mostly perhaps in sheltered lowlands. At a later stage, the strata have been intruded by the products of a widespread volcanic activity which have in places charred the plant remains.

From Hope Bay in Graham Land comes a rich flora representing part of the Upper Gondwana and including several species widely distributed in the Middle Jurassic of Europe, North America, India and the Far East. Snow Hill Island has yielded an impression comparable with the Cretaceous *Sequoia fastigiata* (Sternb.).

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[1] Q. J. G. S., LXXIX, 313 (1923).

[2] A. C. Seward. *Brit. Mus.* (*Nat. Hist.*), *Antarct.* ("*Terra Nova*") *exped.*, Geol., Vol. 1, No. 1 (1910).

	Europe	*India.*	*S. Africa.*	*New South Wales.*	*Queensland.*	*Victoria.*
Lower Cretaceous.	Aptian.				Cape York Plant Beds.	
	Urgonian.	Tripati, etc.			Graham's Creek Volcanics.	
	Neocomian.	Ragavapuram, etc. Umia beds.	Uitenhage series.			
Jurassic.		Jabalpur series.	Enon Coal conglomerate.	Tibooburra beds.	Walloon series. Tiaro series.	
		Kota series. Rajmahal Traps.		Clearance series.		
		Rajmahal Plant Beds.	Drakensberg Volcanics.	Talbragar series.		
	Rhaetic.	Mahadeva series.	Cave Sandstone.		Myrtle Creek series. Landsborough Sandstone.	Wonthaggi Coal M. Cape Paterson beds, Otway & Wannon series.
	Trias.	Panchet (including Parsora and Mangli).	Molteno beds.	Wianamatta stage.	Ispswich series Esk series.	Sandstone & Conglomerate. Shales with *Thinnfeldia.*
				Hawkesbury stage.	Carborough Sandstones.	
				Narrabeen stage.		
	Permian.	Damuda.	Beaufort series.	Upper Coal Measures. { Newcastle Coal Measures. Tomago Coal Measures.		
				Upper Marine series.	Bowen. Series.	
			Ecca series.	Lower or Greta Coal Measures.		
				Upper part of Lower Marine series.	.... Dilly stage.	*Gangamopteris* beds. ?Bacchus Marsh Glacial beds.
	Upper Carboniferous.	Talchir.	Boulder beds and Shales of the Dwyka series.	Lower part of Lower Marine series.	Dinner Creek series Gympie series.	
	Middle Carboniferous.			Kuttung series.		

W. Australia.	*S. Australia.*	*Tasmania.*	*New Zealand.*	*Parana Basin. S. America.*	*Western Argentine.*	*Falkland Islands.*	*Antarctica.*
..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..
			Waikato Heads beds.				
Broome bore.							
Champion Bay & Greenough River beds.							
Mingenew beds.			Waikawa beds. Mataura Falls beds. Mokan beds. Malvern Hills beds.				
			Owaka Creek beds. Hokonui Hills beds. Clent Hills beds. Mt. Potts, beds.	Serra Geral Volcanics.			
	Leigh's Creek Beds.						
		Mt. Nicholas Coal Measures.					
				Botucat Sandstone.			
		Felspathic Sandstones series.					
				Rio do Rasto.			
		Ross Sandstone.					
Cardiff Coal Meas. Collieburn Coal Meas.		Mt. Pellion Coal Measures.		Estrade Nova beds.	Paganzo. System.		Boon. Sandstone.
Irwin River Marine Mudstones. Collie Foraminiferal bed.		*Strophalosia* bed. *Eurydesma hobartensis* beds.					
Collie Coal Meas. Irwin River Coal Meas. Farley stage Arthur River beds.		Bruny Ist. Coal Meas. Mersey Coal Meas. Maria Ist. *Eurydesma cordatum* bed. Minor Glacial bed.				Lafonian.	
Kimberley & Irwin R. beds. with *Paralegoceras Jacksoni*, etc.				Iraty'. Tuberao. Itarare'.			
Lyons Conglomerate.	Inman Glacial Beds.	Wynyard Glacial beds.			Glacial beds.		

LAND CONNECTION BETWEEN INDIA AND OTHER PARTS OF THE GONDWANA CONTINENT.

Having outlined the distribution of the glacial deposits and of the succeeding beds with their individualised flora, we are in a position to enquire what deductions can be drawn therefrom. The sequence and similarity of these widespread rock-groups leave no room for doubt as to their homotaxis. The question of their position in the geological scale has already been considered and the annexed correlation table (pp. 1097-98) expresses the general conclusions drawn.

The comparison of the South African and Indian Gondwana floras is of less importance and interest from the point of view of establishing their homotaxis than as indicating a former distribution of land and sea very different from what now exists. Previous to the geological discoveries we have just been considering, naturalists had appealed to a former land connection, stretching across what is now the Indian Ocean, to explain certain relationships between the living fauna of the Indian Peninsula on the one hand, and South Africa and Madagascar on the other. Dr. W. T. Blanford claimed that the present distribution of certain general birds, fishes, reptiles and land molluscs, is strongly suggestive of a stretch of dry land having formerly extended from southern India to Madagascar. The present-day flora of the Indian peninsula shows some relationships to that of tropical Africa in the prevalence of such genera as *Grewia* and *Impatiens*, as well as in the general absence of the oaks and pines which abound in the Malayan area. The bright-coloured lily, *Gloriosa superba* and other tropical forms in the foot-hills of the western Himalaya and adjoining plains are links with Africa as well as with Afghanistan. The question is not a simple one but it may at any rate be stated that there is nothing in the present-day distribution of animals and plants which is not consistent with the existence of an Indo-African continent in pre-Tertiary times. From the evidence of fresh-water fish, it has been deduced that Africa and South America were also connected with each other as late as the Cretaceous period.[1]

The facts that have been detailed regarding the fauna and flora of the Karroo system show that there is a closeness of relation, amounting to identity and extending throughout the whole of the Talchir and Damuda periods, which is inexplicable unless there had been a continuous land communication along which the plants and land animals could freely migrate between the two areas. And the conclusion is greatly strengthened when we remember that throughout the major part, if not the whole, of this period, a very different type of flora was flourishing in Europe and North America.

The presence in the Uitenhage series of plant forms still with a close relationship to Indian species, makes it probable that the connection between India and South Africa persisted at least into the Neocomian epoch. The indications of a former Indo-African land area thus do not cease with the Triassic period, and the later history of this great continent will receive attention further on in this work, but we may anticipate these considerations by stating that throughout the later part of the Palæozoic and most of the Mesozoic eras, there stretched over a large part of the present Indian Ocean an extensive area of continuous land which included what are now the Indian Peninsula, Madagascar and South Africa, and formed the northeastern corner of a great southern continent; the final dismemberment of this continent is thought to have taken place towards the close of the Mesozoic and early part of the Tertiary eras.

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[1] Tate Regan.

The above conclusion, and even more the proof of the still further extension of the *Glossopteris*-bearing continent over what are now South America, the Antarctic region and perhaps New Zealand, has inevitably shaken the hypothesis of the permanence of continental and oceanic areas. There was at one time a general, though not universal, acceptance of the doctrine that the deep oceanic areas of the present-day have been oceans throughout the whole of the period represented by the sedimentary formations of the geological sequence and that, with the exception of small volcanic islands rising from the depths of the ocean, the dry land of every geological period was confined to the present dry land and the shallower parts of the surrounding sea. The distribution of the *Glossopteris* flora is one of the factors which have necessitated a revision or modification of this doctrine.

CAUSES OF GLACIATION.

For the glacial periods which from time to time have characterised large portions of the Earth's surface no universally accepted explanation has yet been found. Two such periods are well established in the geological history of the world and several others are less assuredly indicated. Confining our attention to the Upper Carboniferous ice age, it is advisable in the first place to get as clear an impression as facts permit of the degree and extent of the frigid conditions.

In India there is no direct evidence that the Talchir ice ever formed a continuous sheet over the whole of that part of the Peninsula now traversed by the basal Talchir outcrops. The occurrence of ice-scratched boulders in India, South Africa, Central Africa, Madagascar, South America, the Falkland Islands and Australia does not of course mean that this vast area, over which they are widely but locally distributed, was at any time completely covered with ice. Against such a supposition are the following facts. In the first place, the intimate association of the glacial beds with the glossopterid plant remains and seams of coal, especially in South Africa and Australia, presupposes the existence of soil-covered exposures of rock amid the ice. Secondly, the glacial stages of the Lower Gondwanas and their foreign equivalents do not connote periods of uninterrupted glaciation. On the contrary, they must have been predominantly pluvial, especially the Talchir epoch in India. This is shown, not only by the presence of coal seams and in Australia and other parts by the interstratified coarse sandstones and conglomerates, but by the moraines themselves, for nearly all the boulders thereof, whether ice-scratched or not are water-worn. David and Süssmilch speak of the breaking up of the ice sheet in Australia into individual glacial tongues by reason of its having invaded old land valleys,[1] and Sir Albert Seward finds nothing against the association of vigorous trees and a dense growth of small plants on the slopes of mountains with ice-filled valleys.[2]

Nonetheless, in the period of the late Carboniferous we find a glaciation, a large portion of whose relics are seen today close to and on each side of the Equator, many of them lying well within the tropics, in latitudes never reached by the ice of the Pleistocene epoch. The suggestion which at one time found a certain amount of favour, that there has been a substantial change in the position of the Earth's axis relative to its surface, no longer finds credence. For one thing it is now realised that the possible distribution of the Upper Carboniferous ice sheets was too wide to be readily explained by any such change alone.

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[1] *Bull. Geol. Soc. Amer.* No. 42, 507 (1931).

[2] *Brit. Mus. Nat. Hist., Brit. Antarct. Exped.* Geol., I, 40 (1910).

It has for a long time been admitted that much of the difficulty regarding the presence of large sheets of ice in what are today warm latitudes, disappears if we accept the hypothesis of continental disruption and displacement. As Dr. Du Toit remarks: "Directly those parts of the earth which bear traces of ice action are concentrically crowded together around South Africa, then the whole area formerly covered with ice becomes of no greater extent than that of the Pleistocene glaciation of the northern hemisphere."[1] Not only is the wide distribution of the tillites made comprehensible by the Drift theory but also their present location in warm latitudes. Both the problems have exercised the minds of scientists for many years past and a solution acceptable to all has not yet been found. The Talchir ice and other features connected with the Gondwana continent have indeed been largely responsible for the support given to the hypothesis of continental drift. Before discussing this hypothesis, however, it will be well to examine carefully what alternative explanations are available.

First for consideration is the refrigerating effect of a continuous land connection between India in its present latitude and the South Pole, and the influence of that connection on winds and currents. Whatever may have been the cause of the Talchir and other cold periods, there can be no doubt, as the writer of the last edition of this Manual pointed out, that their effects would be more widespread and more extensive, and their traces more conspicuous in high latitudes than in low. Nevertheless, the effect of latitude is likely to have been considerably modified, among other things, by the general lie of the landmass. We may surmise that, proceeding from the Antarctic end towards the Indian end of Gondwanaland, the cold in a general way became less. Had the Gondwana continent been symmetrically situated with regard to the Poles, we should expect the cold to have decreased to a minimum at the equator, omitting other climatic factors. Gondwanaland, however, was not so situated but lay, we are now supposing, with one end circumscribing the South Pole, and the other end lapped by the waters of the old Mediterranean sea. The effect of this location in the southern hemisphere, other things being equal, would have been to throw the line of minimum cold to the north—possibly some considerable distance to the north—of the equator. Even today the warmest latitude circle for the year is not the equator but 10 degrees N. latitude. We might expect, therefore, to find glaciation in the Indian Gondwana regions to have been less than it was in similar latitudes on the other side of the equator-line, for instance, than the glaciation in South Africa, Australia and South America. It is difficult to make true comparisons of this kind, but, on the whole, the glaciation in South Africa, probably that in South America and certainly that in Australia, was greater than it was in India. In South Africa the tillite, though never more than a few hundred feet thick in the northern Cape, the southern Transvaal and Zululand, and missing altogether in places farther north, is 800 feet or more in Natal, well over 1,000 feet in Pondoland, and may be nearer 2,500 feet in the southern Cape[2] a thickness never attained by the whole of the Indian Talchir stage, in which the boulder bed seldom exceeds 100 feet. It has been estimated that the Dwyka tillite beds, exposed or otherwise, cover nearly two-thirds of the South African Union.[1] It is not claimed that the whole of South Africa was ever covered at one instant; in fact, the overlap seen in successive stages of the Karroo system on the highlands suggests that much of the country lay uncovered by sediment until well into Triassic times,[2] but it has been suggested that at the period of maximum glaciation the ice formed a continuous sheet across part of the African continent, fully 1,000 miles wide and perhaps little less than that from north to south.[3] There are no grounds for making such a statement in the case of India. Glacial pavements also would seem to be much more widespread and frequent in South Africa than in India. Evidence of glaciation in Australia is on a grand scale; no less than five glacial epochs occurred at intervals throughout a period represented by 10,000 feet or more of strata. About South America we know less, but enough to prove that the glaciation began earlier and lasted longer than it did in India. Dr. Fox has done well to emphasize the shortness of the glacial period in India, where it was not only transient but non-recurrent.[4] There is good reason to believe that refrigeration in the southern hemisphere started before the beginning of the Upper Carboniferous epoch and therefore probably earlier than it did in India. Its main phases terminated before the end of the Upper Carboniferous, but in New South Wales, Queensland, Western Australia, and Tasmania, we find a recurrence of ice conditions during the Permian.

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[1] Du Toit. "Geological Comparison of South Amorica with South Africa," *Carnegie Inst. Wash.* (1927).

[2] A. L. Du Toit. "Geology of South Africa," 2nd. Edit,. 242 (1939).

A point bearing significantly on this argument is the fact that the corresponding deposits in Europe and North America, if not entirely free from traces of glacial action, exhibit nothing approaching the extremely widespread and often thick accumulations of tillite seen in the southern continent;[5] it is true that boulders of rock embedded in fine silt have been found, some of them with a striation believed to be due to the action of ice, but they are sporadic and may be merely the relics left by floating ice-bergs and marking the latitudinal limit which such bergs could reach before melting. Deposits of Upper Carboniferous age within the Arctic circle, where one would expect glacial conditions to have been more severe than they were in lower latitudes, are in most cases equally free from glacial traces. It may be that the Arctic region of those times was largely or entirely a marine area, just as the more immediate neighbourhood of the North Pole today shows less land than that of the South Pole. Furthermore, although the presence of glacial striae and facetting is positive proof of the former existence of glaciers, the absence of such indications can by no means be regarded as evidence that glaciers did not exist. The Arctic region has not yet been fully explored and, in any case, the above remarks regarding the non-recognition of Upper Carboniferous tillites in the Arctic do not apply to the Antarctic region where there is evidence of widespread glaciation during the Carboniferous and Permian around the South Pole.

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[1] W. Howchin. "The Building of Australia", 175 (1925-1930).

[2] A. L. Du Toit. *C. R. Internat. Geol. Cong.* XV., S. Africa, 93 (1929).

[3] A. L. Du Toit; see A. C. Seward. *Q. J. G S.*, LXXX, lxxxviii, (1924).

[4] Unless we except the occasional reduplication of the Blaini Boulder Bed of the Himalaya, where, however, the intervening strata are very thin.

[5] The Upper Carboniferous tillite reported from the Kara river in the northernmost Urals lies well within the Arctic Circle (H. G. Backlund). *C. R. Congr. Geol. internat.* XV, 77 (1929).

The contrast between the ice of the southern continent and the apparent absence of glacial relics from the bulk of the homotaxial strata of the northern hemisphere might be taken to point to some different scheme of land and water distribution. Even today the Antarctic cold is more rigorous than the Arctic, a result of the terrestrial nature of the South Polar region as compared with the prevailing marine conditions around the North Pole. The extension of the Gondwana continent to the Antarctic region would have thrown Antarctic conditions further north than they now attain, and the shape as well as the enormous size of the continent would have modified the flow of equatorial currents and might have assisted in some way in impounding cold waters in the southern ocean. Continental climate is notably severe. That climate is far from being a mere matter of present-day latitude is seen in other periods, and is well illustrated by the contrast in Silurian times between the stunted fauna of the Pacific province and the rich coral-reef fauna of the Boreal and Atlantic regions, a reversion of modern conditions which has led to the suggestion that the Earth's axis of rotation at that time may have terminated at one extremity *in* the Pacific and at the other in the Indian Ocean.

It has been estimated that to bring about a descent of glacial ice to sea-level near the parallel of 34° S. in Australia under present conditions, a fall in temperature of not less than 10°C. (18°F.) would probably be necessary.[1] That a different scheme of land connection, assisted or not by somewhat higher and perhaps steeper topography, could produce such a fall is by no means incredible. Such a drop in temperature, in fact, would be considerably less than the difference in temperature observable today between localities situated on the same latitude. The average winter temperature of the northern part of the United States is considerably below that of the portions of western Europe lying between the same latitudes ; the lowest temperature during the year in Valentia (southwest Ireland) averages some 45°F., while at Nerchinsk, which is on the same latitude in eastern Siberia, it is about(–)19°F. The presence of ice near sea-level in the Talchir period not only near but on both sides of the equator is, however, a different matter, and to explain it as due to a peculiar distribution of land and sea seems frankly impossible.

The two fundamental factors governing temperature on the Earth's surface are latitude and altitude. If, therefore, a cold climate of the past were not the result of a high latitude, it is natural to enquire whether it could have been due to high altitude. In a great number of cases the Upper Carboniferous tillites of Gondwanaland, even in the low latitudes of India, are found at quite low levels, and the general conclusion is that in South Africa and Australia the ice moved over a country of low relief. South Africa at that time was a peneplain of small height and its mountains could not have ascended more than a few thousand feet ; the highest land in South Africa, just before the onset of the Carboniferous glaciation, lay over the Windhoek highlands, Griqualand West and the Transvaal but, in Du Toit's opinion, few ridges are likely to have exceeded 5,000 feet above sea-level.[2] At the same time, the flow of the ice was everywhere towards the south, and country of comparatively high altitude in the more northerly tracts of the African region may have formed the snowfields which provided the glaciers of the south with ice. Some of the inclusions in the Dwyka tillite can be shown to have been transported for hundreds of miles.[1] Similarly, we might suppose that the ice which has left its mark in the Damodar and other Indian valleys derived its origin from snow which fell many miles distant upon a more exalted terrain. On *prima facie* grounds it seems likely that a land-mass as vast as that of the old continent of Gondwanaland included lofty plateaux and mountainous tracts, fit to form the gathering ground of extensive ice-sheets and glaciers. There has perhaps been a tendency to exaggerate the importance of this argument, but the presence of high country, though inadequate by itself to account for the extensive glaciation within the Tropics, must have been a contributory cause. What it fails principally to explain is the low level reached by the glaciers.

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[1] T. W. Edgeworth David. *C. R. Congr. Geol. internat.* Xé, Mexico, 453 (1906).

[2] "Geology of South Africa", 2nd Edit., 496 (1939).

Steep drainage lines would increase the velocity of flow and assist in bringing the ice to lower levels, but the effect would not be great and there is no collective evidence to show that gradients were unusually steep. In certain parts of Natal and Zululand, differences in level of the glacial floor amounting to 800 feet within a mile or two have been recorded, and higher figures still are quoted in the case of Griqualand West. There are, however, no signs of unusual steepness of gradient and rapid flow near the margins of the ice sheets and ends of the glaciers, especially where they approach sea-level, and it is precisely this attainment of sea-level by the ice which seems so abnormal in low latitudes.

The subject of past climates is one which admittedly involves a complicated group of problems but, even allowing for maximum effects and extreme condition, many geologists find it impossible to attribute the unusual features of the Gondwana ice age to a drastic difference in the distribution of land as compared with modern geography, combined with a difference in altitude and steepness of terrain, sufficient to explain the facts that precipitation took the form of snow as well as of rain over the tropical parts of Gondwanaland in Upper Carboniferous times, and that the glaciers or ultimate fingers of the ice sheets actually reached the sea and broke off in the form of ice-bergs, as they seem to have done in the Salt Range area and other parts. The suggestion that the Talchir ice age and other glacial epochs were the result of some peculiar cosmic change, and due predominantly to variation in the heat of the Sun, seems rather to beg the question and savours too much of a "*faute de mieux*" argument.

We come thus to the theory of Continental Drift, and it must be conceded that it provides a simple explanation of most of the relevant facts. This is not the place to discuss the theory in full or to summarise the recent advances made along this line of enquiry, after the very able synopsis drawn up by Dr. Van der Gracht and the illuminating publications of Dr. Du Toit.[2] Its bearing upon many of the problems of Indian geology, however, come within the scope of this work, and cannot be ignored, in spite of the immaturity of some of the ideas involved and the inevitable want of unanimity as to its acceptance.

Taking Dr. Du Toit's map of the old intact Gondwana continent as a basis (" Our Wandering Continents", Fig. 9), it will be seen that, in that attempted reconstruction of ancient geography, South America has been brought close to Africa, Madagascar is shifted northwards to fit into the Zanzibar coast. India and Ceylon are brought down so that the Gulf of Cambay is opposite Cape Guardafui, while off the east coasts of Africa, Madagascar and India is a large central land-mass covering the greater part of the present Indian Ocean and fitting into what is now the south coast of Australia. To fit the pieces of this geographical puzzle together, it has thus been thought necessary, not only to displace the various continents from their present position, but to twist them through varying angles. Dr. Du Toit has given Australia a twist approaching 90°. To India he has given a smaller twist of about 30°, not so much to fit its present shape into the outlines of Madagascar, East Africa and Antarctica—for the west coast of India is a feature dating probably from the Tertiary and formed perhaps after the northward drift of the Indian land-mass—but, presumably, in order to bring the strike of the ancient rocks of these four regions into conformity with one another. If India be given a clockwise rotational twist of about 30° relative to Madagascar, the " grain " of the two regions becomes more nearly identical. In any case, the Indian portion of Gondwanaland is supposed to have broken off and moved in a direction between N.E. and N.N.E. until it was obstructed by a northern continent covering northern Asia and Europe which may have been moving Southwards to meet it. Whether the actual coasts of the two continents touched each other at any point cannot be stated but, for the most part at any rate, we must suppose that the last phase of the approach of the southern towards the northern continent disturbed the floor of the narrowing sea which separated them. This sea-floor rose and shared the severe buckling which then began to affect the margin of the southern and presumably also that of the northern continent. The general tendency of the corrugated margin of the southern continent was downwards beneath the sediments of the Tethys. The southern margin of the Angara continent may also have been thrust southwards beneath the same sediments. The combined effect of the mutual approach of these two continents would thus be to lift up the broad belt of Tethys sediments which at the same time suffered severe plication. In this way rose the plateau of Tibet, the northern edge of which shared in the formation of the Kuen Lun, and the southern in the formation of the Himalaya, as well as of the system of mountain chains stretching from the western end of the Himalaya through the North-West Frontier and Baluchistan into Persia and beyond, and the mountain belt extending from the eastern end of the Himalaya through Burma, Malaysia and the East Indies.

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[1] A. L. Du Toit. *C. R. Congr. Geol. internat.*, XV. S. Africa, 91 (1929).

[2] The reader is referred especially to the following: F. B. Taylor. *Bull. Geol. Soc. Amer.*, No. 21, 179-226 (1910); A. Wegener. "The Origin of Continents and Oceans", London (1924); Van der Gracht. "Symposium on the Theory of Continental Drift," *Amer. Assoc. Petrol. Geol.* (1928); A. L. Du Toit. "Our Wandering Continents" (1937).

Such is a brief outline of the suggested march of events. It may be some time before it is possible to decide whether this theory is to be definitely accepted, rejected or modified, but the following are a few considerations worthy of *interim* attention.

The alternative idea most favoured by opponents to the Continental Drift Theory is that the contraction of the globe due to the gradual cooling of its molten contents was responsible for the wrinkling of its crust, and that mountain ranges are analogous to the ridges which form on the skin of a drying and contracting apple. That such contraction has taken place and has affected relative displacement of the crust may well be true, but that it could be an adequate cause of the piling up of mountain belts like those of the Himalaya or the Alps is not so easy to accept. In any case, this theory also pre-supposes relative lateral movement of portions of the earth's crust towards or away from each other. This conclusion must follow from the fact that the wrinkling is on a very coarse and not on a fine scale. In other words, there must have been a considerable drift of the crust towards each large wrinkle, especially towards any wrinkle of the magnitude of the Himalaya. Had the wrinkles been small and distributed more or less uniformly over the earth's surface, relative lateral movement of the crust at any one point would have been practically negligible ; it is the localisation of the wrinkles along well-marked widely separated lines where they attained an immense size which seems to demand an appreciable crustal drift towards each wrinkle. This would presumably involve converse conditions in the tracts between the wrinkles, where portions of the crust would tend to split off from each other and drift apart. In fine, the theory of wrinkling due to contraction or cooling appears to be dependent also upon a modified form of lateral continental drift, when applied to the actual facts of the Himalaya, the Alps and the Andes.

The piling up of the Himalaya, though assisted perhaps by intrusions of granite bathyliths, could not have come entirely from below. The severe compression and resultant overthrusting and recumbent folding of sedimentary strata, characteristic of the Himalayan and other great mountain chains, seem to demand a compensative tensional sliding on a large scale in neighbouring parts of the Earth's crust accompanied by lateral movement of large sections of that crust. The aggregate length of such tensile slides—thrust-planes of a *minus* character—would have to be a matter of several hundred miles. No such disruptions can be recognised in the Indian Peninsula, and the conclusion would seem to be that the portion of crust forming what is now the Peninsula moved as a whole northwards ; in other words, that it "drifted" or shrank northwards to compensate the great reduction in area caused by the plication of its northern margin. The tensile slides, or something equivalent, we must suppose to have been located further south in the Indian Ocean. Crustal movement, accompanying mountain folding, has been tacitly accepted for a very long time without perhaps a realisation of the scale of such movement. The shortening of a length of crust due to the formation of a chain like that of the Himalaya must have been many times the present width of the range. There can be no doubt that before the formation of the Himalaya the site of Cape Comorin was much further—probably several hundreds of miles further—away from central Asia than it is today. The crust-shortening in the Alps is now thought to have been at least 4 to 1 and may have been as much as 8 to 1 ; the compression of these mountains meant a relative movement of their southern limit northwards for a distance which has been variously estimated at 350 miles, 1,035 miles and intermediate values. The compression in the Himalaya is likely to have been greater than it was in the case of the Alps. If the Indian Peninsula were pulled southward or rather S.S.W.-ward until the Himalayan folds had all been flattened out and its thrusts replaced, Cape Comorin would find itself probably well south of the Equator.[1] We have spoken above as if the Himalayan compression were the cause of the drift, but it would be equally logical, in the present state of our knowledge, to assume that the drift was the cause of the compression, or that both phenomena were results of some unknown cause. In the same way a drift westward of South and North America from Africa and Europe, respectively, might have been the accompaniment of the piling up of the Andes and the Rocky Mountains.

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[1] If we include in this straightening process the rest of the Asiatic mountains as well as the Himalaya, and use a basis of only 4 : 1, the drift inferred would be of the magnitude of 3,000 kilometres, bringing Cape Comorin very close to Madagascar. Treated in a similar manner, the straightening out of the Alps would easily fill up the Mediterranean. (Van der Gracht. Symposium on the Theory of Continental Drift; *Amer. Assoc. Petroleum Geol.*, 54 (1928)).

In the above example we have imagined one edge of the shrinking land-mass to be more or less fixed relative to the Earth's axis. The conception of such a shrinkage, involving as it does a drift of the unfolded towards the folded mountainous margin, is however not enough. If we suppose that the mountain belts were in all cases fixed lines relative to the Earth's axis and that crustal movement was confined to a creep or drift of land towards these stationary folded margins, we get no nearer to a solution of the Upper Carboniferous ice age problem. We should still have to account for an immense area of glaciated country many times larger than both our modern Arctic and Antarctic regions put together. We should still find glacial boulder beds at sea-level within the Tropics and along the Equator. The Talchirs of the Indian Peninsula would, in fact, be brought down very close to the Equator, while their equivalents, the Blaini beds and the Salt Range Boulder beds, would occupy lower latitudes than they do now.

If we bring ourselves to accept the shrinkage of continental masses (the "Intracontinental drift" of Van der Gracht) as described above, is it possible to go a step farther and to accept a bodily drift of land-masses as a whole, *i.e.*, a movement relative to the Earth's axis of every portion of such a mass, whether in a state of plication or not? Only by such an extension of our conception can we gain assistance from the Wegener theory of Drift in understanding the Gondwana ice age. Only by a northward drift of several thousand miles could we in this way explain the presence today of glacial tillites at low altitudes in the Tropics. It seems necessary, therefore, if the Drift theory is to explain the present distribution of the Talchir boulder beds, to accept a drift northward not only of India, but of Africa, South America, Australia and probably New Zealand. The shape of the submarine shelf which bears the Kerguelen Islands and St. Paul and extends eastwards to the Macquaries, is suggestive; assuming this shelf to be a submerged part of the Antarctic land-mass, we should have just as much incentive to suppose that South Africa and more especially Australia drifted northwards away from the Antarctic region, as we have for suggesting that the Americas broke away from Africa and Europe.

Before the occurrence of any drift and before the plication of the Himalaya, the Alps, the Andes and other mountain systems, the Gondwana continent might thus be visualised as enveloping the South Pole, with its ice-sheets extending irregularly northwards, and its margins occupied by the geosynclines by which its boundaries can be traced. The first change would have been the formation of immense slanting fissures widening into broad seas as the ruptured portions of land drifted apart. These fissures and the broad belts of attenuation which they initiated would have to be regarded as something more than the counterparts or *minus* equivalents of the mountain belts of thrusting and overfolding which were formed a little later along other portions of the continent, especially along its margins, for they also represent compensation for the bodily drift ("Inter-continental drift") of the moving land-mass. One of the great fissures, though as irregular in its course as a thrust-plane, must have had a general latitudinal direction; others were presumably more or less longitudinal but equally irregular, one dividing South America from Africa, another Africa from India, and a third India from Australia. The drifting apart of these land-fragments, it is supposed, took place eastwards and westwards as well as northwards, and not necessarily at the same time.[1] The greatest northerly drift, that of India, was accompanied by the formation of the Himalayan mountain system along a line at right angles to the direction of movement. The least northerly drift is shown by South America, whose physiography and structure lines are dominated by a westerly movement away from Africa, accompanied by the formation of the Andes, here again at right angles to the direction of movement. In Africa we seem to see effects intermediate between those of South America and those of India. The drift northwards is less than that of India but more than that of South America ; its post-Palæozoic tectonics, at the same time, are not so exclusively N.-S. as are those of South America, nor so E.-W. as those of India.

The mountain system of consecutive arcs, one after the other, along the confines of India and Burma, would be readily understood as the result of the impingement of one continent with its headlands and bays against the margin of another—or rather against the upfolded sediments off its coast. This point is referred to again in a later chapter, but appearances are exactly those described, the capes and headlands of the southern land-mass corresponding to the nodal points between which the rock waves curve southwards to form the series of mountain arcs. As would be expected, these arcs in practically all cases are convex towards the Indian Peninsula. The deepest penetration of this land-mass into the Tethys sediments must evidently be regarded as having taken place at the head of the Assam valley. Not only does this region appear to represent the northeast corner of the Gondwanaland, where the coast swung round from W.-E. to N.-S., but the corner seems to have been a particularly sharp head-land, judging from the way the rock waves have tucked themselves round it. *A priori*, it might be expected to have been the first point of obstruction between the two continents, one of which, we may imagine, was moving N.-N.-E. wards into an enormous open bay comparable to the Great Australian Bight. This conclusion perhaps derives some measure of support from the fact that the Gondwana tillite has been recognised on the north side of the Great range at this end of the Himalaya ; elsewhere, it and other Gondwana strata have been identified only in the Lesser range to the south of the main chain.

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[1] There has been wide diversity of opinion as to when the various " drifts " took place. For instance, the mutual separation of South America and South Africa was thought by Taylor to have taken place in Permian times. Tate Regan, on the other hand claims that, from the evidence of fresh-water fish, these two continents must have been connected with each other as late as the Cretaceous period. Du Toit supposes that India began to drift away from Africa and Madagascar early in the Cretaceous. Many of the French geologists of Indo-China believe with Fromaget that " les poussées paroxysmiques du Continent de Gondwana contre l'aile droite de la virgation de l'Archipel asiatique " were in full force in the Noric epoch. Whatever the date of the hypothesised drift may have been, it has been generally supposed that the eastern portion of the Tethys Sea remained closed throughout the greater part of its history, and that land communication between Angaraland and Gondwanaland existed in the vicinity of the Shan States of Burma and was only occasionally broken—if broken at all—between early Palæozoic times and the early Tertiary final phase of the Tethys gulf (See La Touche. *Mem.* XXXIX, Pt. 2, pp. 350 and 355 (1913); also Coggin Brown. *Rec.* LVI, 87-88 (1924)). The existence of such an almost permanent land bridge between the two continents is not easy to reconcile with the theory of Drift as applied to the Indian Peninsula. The presence of such a bridge has been invoked to explain, among other things, the discordancy between some of the Palæozoic faunas of Burma and faunas of approximately the same age in the Himalaya ; whether such lack of faunal affinity between the two regions might be attributable to their belonging to the coasts of different and widely separated continents is a conjecture for future investigations to verify or disprove. Incidentally, it cannot be definitely concluded that continental drift, if it occurred at all in Mesozoic or Tertiary times, had not taken place before. The presence of a luxuriant and almost tropical coral fauna of Silurian age in high northern latitudes of Scandinavia rather suggests an ancient drift towards instead of away from the Poles.

Chronologically the above conjectural disquisition belongs to a later chapter if we are to believe that it was the Cretaceous or early Tertiary period which witnessed the fragmentation of Gondwanaland affecting the separation of India. Summing up, it must be admitted that, in spite of as yet unsolved difficulties the present distribution of the Upper Carboniferous tillites of the Southern Hemisphere is best explained on the assumption that they were originally concentrated much nearer the South Pole than they are today, and that it was the northward component of a drift affecting the disrupted land-masses which brought such witnesses of an icy climate up to the Equator and beyond.

Other glacial epochs in which the ice reached comparatively low latitudes were the Lower Cambrian, of which definite evidence has been recorded in South Australia (30°-35°S.) and China (Yangtze valley, about 31°N.), and the pre-Cambrian, of which indications are thought to exist in South Australia and are unquestionable in South Africa. In the northern and central portions of South-West Africa (around latitude 23°S.) a tillite—the Chuos Tillite—attaining locally a thickness of 1,500 feet, forms part of a sequence corresponding to what has been termed the Archæan in this work.[1] Other tillites of later but still pre-Cambrian age have been recorded near Johannesburg (a little above latitude 23°S.) in the Government Reef series, corresponding probably to our Purana ; in these deposits are striated boulders over a foot in length.[2] Another tillite with striated and facetted boulders occurs in a younger but still possibly pre-Cambrian formation, the Griquatown series, while a yet younger tillite—the Numees Tillite—has been found in Namaqualand in the Nama, a system which may correspond to the Cambrian.[3] The glacial zone with its scratched pebbles and boulders in the Table Mountain series (Upper Silurian to Lower Devonian) resembles in many respects the Dwyka Tillite exposed a few miles distant.

Of the proximity of oceans to the Talchir ice-sheets evidence is to be found in marine beds along the borders of the glaciated areas ; such are to be seen in the Salt Range, south Rewah, the eastern Himalaya, South-West Africa, Brazil, Western Argentina, Western Australia, New South Wales, the Springsure district of Queensland, and Tasmania. In the southern parts of Cape Colony, the ice front appears to have floated off into an extensive body of fresh or brackish water.

EVOLUTION OF THE WORLD'S FLORAS.

Almost as mysterious as the extent and distribution of the glacial deposits are those of the *Glossopteris* flora which in places accompanied and everywhere followed them. In the history of the world's vegetation, the earliest known assemblage of plants worthy of the term flora is that of Upper Devonian and Lower Carboniferous times. The outstanding feature of this flora is its cosmopolitan character. Whether in the Arctic regions, northeast Greenland, Spitzbergen, many parts of Europe, North America, South America, South Africa, China, Australia and elsewhere, from one end of the world to the other, there flourished the same uniform type of plant assemblage, characterised by such forms as the archaic horsetail, *Archæocalamites ;* the lycopods, *Lepidodendron, Ulodendron* and *Bothrodendron ;* the unplaced genera belonging perhaps to the pteridosperms, *Archæopteris, Adiantes, Cardiopteris* and *Sphenopteris* ; the ferns, *Rhacopteris* and *Clepsydropsis ;* and the special type, *Sphenophyllum.* Sir Albert Seward finds no grounds for assuming any essential differences in the broader features of the vegetation throughout the world at this time, and one of its conspicuous characteristics is the occurrence of the same genus or even species in widely separated regions.[1] On both sides of the Tethys, the ancient sea which covered a large portion of Asia during the Palæozoic and Mesozoic periods and stretched westward through southern Europe, this monotonous flora persisted until Upper Carboniferous times. Some of its genera found in the southern parts of Gondwanaland are known to have flourished well within the Antarctic Circle. Of this old flora the balance of evidence favours the view that the ancient continent of Atlantis, of which Greenland may be a relic, was the chief centre of dispersal.[2] The *Rhacopteris*-bearing horizon in the Po series of the Punjab Himalaya is the only known example in India of this older flora.

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[1] Du Toit. " Geology of South Africa ", 2nd Edit., 46 (1939).

[2] *Ibid.*, 69.

[3] *Ibid.*, 141.

During the prolonged period of the Upper Carboniferous, this uniformity was disturbed and a remarkable differentiation took place into two sharply contrasted major botanical provinces, a Northern and a Southern, corresponding to two great continental regions, widely but not entirely separated from each other. In the Northern province a rank vegetation covered an enormous total area of swamp and low hills; in the Southern a less luxuriant type flourished in proximity to retreating glaciers over a vast continent. The southerly continent was christened by Suess Gondwanaland, while the northern province, known as Angaraland, included a continent stretching from Russia eastwards to the Pacific, with a large southeasterly extension, Cathaysia, covering Burma, Indo-China, Malaysia and the East Indian archipelago. Sir Albert Seward has alluded to the danger of making hasty generalizations on the subject of fossil plants as tests of climate.[3] Many recent plants can live and reproduce themselves in Arctic as well as temperate lands, and it is possible for tropical species to adapt themselves to cooler conditions. Certain it is that the genus of a plant gives us no clue to climatic conditions or temperature. *Gleichenia* is instanced as one of the commonest ferns in the Tropics but the genus includes species which grow vigorously at altitudes of 10,000-12,000 feet; many other examples of such adaptation could be cited.[4] Nevertheless, the differentiated Southern province of the late Palæozoic flora is associated so closely with the great cold period which affected it, that the ice which carried the Talchir, Dwyka and various other boulders and pebbles, is naturally assumed to have been mostly responsible for the change, just as the Pleistocene glaciation was largely the cause of the distinction between modern European floras and those of North America and China. At the same time, from the evidence in South Africa, and less definitely in Australia and South America, it is to be inferred that, although there is a definite phytological break between the beds carrying the old *Rhacopteris* flora, as it is called, and the first appearance of the glossopterids, the change was not brought about without a struggle on the part of the older flora. The first glacial epoch in New South Wales seems to have been of too transient a nature to affect the vegetation, and we find abundant examples of the *Rhacopteris* flora 1,230 feet above the lowest tillite. The second set of glacial deposits are some 4,700 feet thick and obviously represent a cold climate of prolonged duration, and yet we find *Rhacopteris*-bearing strata at intervals throughout, especially in the upper half of the stage, and persisting to near the top. Lower Carboniferous plants in the northern hemisphere also flourished with vigour well within the Arctic Circle. There must, therefore, have been places where the *Rhacopteris* flora found shelter from, or in other ways succeeded in surviving, a long period of severe cold; the great majority of its members disappeared from the Southern province before the Talchir epoch.

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[1] A. C. Seward. *Q J. G. S.*, LXXX, lxii and lxxiv (1924).

[2] A. C. Seward. *Q. J. G. S.*, LXXX, lxx (1924).

[3] *Q. J. G. S.*, LXXX, xcvi (1924).

[4] See Seward. *Brit. Ass.*, p 213 (1929).

Although the general lowering of the temperature, which must have preceded the ice age itself, seems to have been responsible for the initiation of the *Glossopteris* flora, the latter as a whole can in no sense be regarded as exclusively a glacial flora. Sahni points out that there are apparently no traces of ice action in the rocks underlying or associated with the Gondwana plant beds of the invaded Northern province of Angaraland, from which it is obvious that these immigrants had already become accustomed to a warmer climate.

Two facts point definitely to the conclusion, however, that the *Glossopteris* was still more capable than the *Rhacopteris* flora of enduring and surviving the rigours of an Arctic climate. In the first place, unless we accept the unlikely hypothesis of a change in the position of the Earth's axis relative to its surface, the discovery of *Glossopteris* types in the Antarctic, only 300 miles distant from the South Pole, witnesses to the power of the flora to flourish in the extreme cold of the Polar regions. Secondly, in South Africa, South America and Australia, members of the *Glossopteris* flora occur below and amongst, as well as above, some of the tillite, proving that the differentiation in the world's vegetation had commenced in these parts at any rate, before the end of glacial conditions. At Vereeniging in the Transvaal, leaves of *Gangamopteris* have been noted among the boulders of Dwyka conglomerate at the actual point where they rest directly on a striated pavement of older rocks; above the *Gangamopteris*-bearing sandstones of the same area is some redistributed tillite and this is followed by a thin succession of beds with Triassic plants. At Bacchus Marsh in Victoria also, *Gangamopteris* and *Schizoneura* have long been known to occur interstratified with the glacial deposits.

The Northern Province.—In the Northern province, which included the ancient continent of Angaraland covering much of Siberia and Russia, there is also a phytological break but of a less revolutionary character, and the old cosmopolitan *Rhacopteris* flora suffered but few and normal evolutionary changes in giving place to the lepidodendroid type. Many of the old forms persisted but several new forms made their appearance and the vegetation, still in the main homogeneous, became much more luxuriant, covering a monotonous landscape of swamps. Northwards it reached at least as far as Melville Island and Banks Land, while to the south it can be traced to Afghanistan, southwest Persia[1], and other portions of the northern shore of the Tethys. Westwards it flourished in North America, and eastwards many of its types have been recognised in the vast coalfields of China. Members of the Northern flora have been identified in Sumatra and the Malay peninsula, countries which formed part of the Cathaysian extension of the Angara continent, while some of the vegetation of central Shan-si agrees closely with that of North America and Europe.

There is no evidence of glacial conditions and the term tropical has been applied to the climate under which this Northern flora existed. Whether this word is justified or not is a question which has been discussed by Seward and others.[1] A recent study by Dr. Eric Norin of the chemical composition of the sediments containing the plant remains in the Shan-si province of China has led to the opinion that the beds and their *Gigantopteris* flora accumulated in a very damp tropical climate.[2] Sahni cites, as evidence in favour of the same conclusion, the frequency with which the Palæozoic "tree-fern", *Psaronius*, so common in the Permian forests of Europe, is seen to bear epiphytic growths among its aerial roots.[3] A general absence of well-marked rings of growth in the wood of the trees indicates perhaps the absence of sharply contrasted seasons, but the conclusion seems valid that the climate of Angaraland was much more genial than that of the Gondwana continent during the Upper Carboniferous and early Permian epochs, and cherished a much more luxuriant vegetation, perhaps comparable to that of present-day tropical forests.

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[1] The *Sigillaria* found in the Bakhtiari country of southwest Persia belongs probably to this northern province; it is described as close to *S. brardi*, a species found in the English Upper and Middle Coal Measures and elsewhere in the uppermost Carboniferous and Lower Permian [A. C. Seward. *Phil. Trans. Roy. Soc.*, 221, B, 377 (1932)].

It was in Upper Carboniferous times (Middle Coal Measures) and in this province that the family of lycopods reached their culmination, represented chiefly by *Lepidodendron* and *Sigillaria*. Among the Equisetales the predominant form was *Calamites* ; there were numerous examples of pteridosperms and ferns, and in addition a few species of cycads, cordaitalids and sphenophyllalids made their appearance.

Although the Northern, *vis-a-vis* the Southern, may be regarded as a single botanical province, it can be differentiated by certain not very pronounced peculiarities,into three sub-provinces : (i) the Arcto-Carboniferous, characterising parts of Europe and eastern North America and possibly with some connection across a portion of the Arctic regions, (ii) the *Gigantopteris* flora, covering western North America and China, extending southwards to Sumatra, with perhaps a connection across the other side of the Arctic regions, and (iii) the Angara flora, stretching across Asia from the Urals to the Pacific and southwards to the vicinity of Kashmir. From the Indian geologist's point of view, the most important of these floras or sub-provinces are the *Gigantopteris* and Angara ; the latter was composed to a large extent of genera and species peculiar to itself, but included a few elements of the other two Northern sub-floras.[4] As will appear, both the Angara and *Gigantopteris* sub-floras include a few immigrants of the Southern or *Glossopteris* assemblage.

The Southern Province.—With regard to the Southern province, whose confines have been already outlined, a marked change in the climate seems to have extinguished most but not all of the old forms of vegetable life. There is little doubt that the new flora, the *Glossopteris* flora, originated in the south, perhaps on a Palæozoic predecessor of the Antarctic continent[5], but of the stages by which it evolved nothing is known. Once established, however, it not only held its own but, as will be shown, invaded the Northern province.

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[1] "Plant Life through the Ages", 2nd. Edit., 253 (1933).

[2] *Geol. Föreningens I Stockholm Förhandlingar*, Jan.-Feb., 1924, p. 39 ; see also T. G Halle, *Pal. Sin.*, Ser. A, Vol. II, Fax. I, 11-12, 291-292 (1927).

[3] *Journ. Ind. Bot. Soc.*, Vol. XV, 322 (1936).

[4] B. Sahni. *Current Sci.*, IV, No. 6, 385-390 (Dec., 1935) ; *Proc. Ind. Acad. Sci.* (1936).

[5] Seward. *Brit. Ass.*, 210 (1929).

Character of the Glossopteris flora.—The Glossopteris assemblage, the four essential forms of which were *Glossopteris, Gangamopteris, Phyllotheca* and *Schizoneura* was one of the most notable and widespread of fossil floras, and bears evidence of a remarkable change in certain features of the vegetation in the southern hemisphere. As in the Northern province, the same ancient plant groups of the Lower Carboniferous still find a place in the flora which soon becomes enriched by the appearance of cycads, conifers and the Ginkgoales, though the genera differ from those of the north, and the flora as a whole is more meagre. It is distinctly a land flora, and apparently composed largely of plants of low growth and very broad leaves. *Calamites* and its prototype, *Archæocalamites*, both persisting in the Northern province, are unknown in the late Palæozoic rocks of Gondwanaland, their place being taken by *Phyllotheca* and *Schizoneura*. *Phyllotheca*, the more abundant and more varied genus, is found in all the four most important sub-provinces of Gondwanaland, but is especially characteristic of Australia where Arber suggests it may have originated.[1] *Schizoneura* is a more distinctive type and, though occurring in South America, is rarely found outside India, where it seems to have first appeared and whence it may have spread to more distant regions; it did not attain its maximum distribution till Triasso-Rhætic times. *Glossopteris* and *Gangamopteris*, between which it is not always easy to distinguish, are the two most familiar forms of the flora and are related probably more to the pteridosperms than to the ferns. In both these forms, which flourished in such abundance that in some places whole beds appear to be made up of their remains, "we have fronds pre-eminently characteristic of the southern type of flora, and quite distinct in form and nervation from any known representative of the northern province." Both are found nearly everywhere within the boundaries of Gondwanaland.

One of the marked features of the *Glossopteris* flora is its widespread and uniform character, several of the forms in widely separated regions being specifically identical. *Glassopteris browniana*, for instance, has been recognised in India, Australia, Tasmania, South Africa, East Africa, South America, and the Falkland Islands ; *Glossopteris indica* in India, Tonkin, Australia, Tasmania, South Africa, South America, the Falkland Islands and Antarctica ; *Gangamopteris cyclopteroides* in India, Australia, Tasmania, South Africa, South America, the Falkland Islands and Antarctica ; *Cordaites* (*Noeggerathiopsis*) *hislopi* in India, Australia, Tasmania, South Africa, East Africa (?) and South America. *Neuropteridium validum*, *Sphenopteris polymorpha* and other forms, though not quite so ubiquitous, also have a wide geographical range.

Northern types in the Southern province.—In the Southern province, very few members of the old pre-*Glossopteris* world flora found it possible to adapt themselves to and persist under the new conditions. Such survivals, however, can perhaps be identified in the so-called "Northern types" which in certain parts of Gondwanaland are found mingled with the new vegetation. Professor Sahni has suggested that some of them at least are not necessarily emigrants from the Northern province but survivals or descendants of the old cosmopolitan flora. It would not be easy to distinguish between such survivals and genuine migrants from the north, but it seems highly probable that many of these extraneous types are persistent relics of the Lower Carboniferous flora. At the same time it will be convenient to refer to them as Northern types, meaning by that term simply that they have closer relationships with the Northern flora —*i.e.* with a vegetation which had changed less since Lower Carboniferous times—than they have with the *Glossopteris* assemblage amongst which they find themselves. A few examples will illustrate this point.

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[1] Arber. *Brit. Mus. Cat. Gloss. flora*, p. xxiii (1905).

[2] Arber. *Ibid.* xxvi.

Of all such Northern forms, the lycopods, which had been particularly abundant and widely distributed during the earlier Carboniferous epoch, are the most numerous and widespread of the extraneous types found in the Gondwanas of South America and South Africa; as examples we may cite *Lepidodendron pedroanum* from the Upper Carboniferous of Brazil, a form found in the Lower Carboniferous of the Argentine and practically indistinguishable from a species in the pre-Gondwana rocks of Peru, and *Cyclostigma leslii*, a species found in the Ecca series of South Africa and also in the pre-Gondwana rocks of the same region. Other localities in South America yielding Northern forms are Gachala in Colombia—with *Calamites, Cordaites* and *Neuropteris*[1]—and Cochabamba in Bolivia where *Lepidophloios* is found in beds lying beneath fossiliferous Uralian rocks.[2] In the South African Ecca beds, there are more than one species of *Lepidodendron* and *Sigillaria* including the above-mentioned *Lepidodendron pedroanum*, a species of *Psygmophyllum*, and some seeds of Northern type. *Rhacopteris*, a pre-Gondwana genus, is associated with *Glossopteris* and *Gangamopteris* in the Argentine and is regarded by Sahni as most likely a survival, in spite of the fact that the old *Rhacopteris* flora, although well represented in eastern Australia, has so far not been observed in South America in beds antedating the appearance of the *Glossopteris* flora.[3] *Voltzia heterophylla* is another typical Northern form sometimes found in the southern continent.

In South Africa and South America, therefore, *i.e.*, in the western half of Gondwanaland, there is clear evidence of the admixture of the Southern and Northern types of vegetation, the interpretation of this association being either that the Northern types migrated southwards from the Angara continent or, what seems more probable, that the majority of them are survivals or descendants of a few of the older plants which evolved along the same lines they took in the north and found it possible to adapt themselves to conditions very different from those of the forest swamps of Europe and north America. In a few cases, it seems easier to believe in the migration of certain Northern forms from north to south, and since we have some evidence of land connection between the two great continents there may well have been some movement of plant types in this direction as well as the more definite and perhaps more extensive invasion from south to north.

Cases of such admixture, if present at all, are rare in India and Australia, where the flora is of a purer glossopterid character, but *Calamites* is recorded from the Lower Coal Measures of New South Wales, and the scrambling or climbing plant known as *Sphenophyllum* (*Trizygia*), found in both those countries as well as in South Africa, appears to be a Northern form, dating back to the Upper Devonian, while a doubtful specimen of *Bothrodendron* has been described from the Lower Gondwanas of India. Lastly, there is a suggestive resemblance between a plant axis named by Feistmantel *Dictyopteridium sporiferum* from the Raniganj rocks of the south Rewah basin, and Gothan & Sze's *Rhizomopsis gemmifera* from the Permian of China, a species which may really belong to the genus *Gigantopteris*.[1] As an example of survival, attention may be drawn to the widespread Southern form, *Cordaites* (*Noeggerathiopsis*) *hislopi*, which, it is not impossible, may have been derived from some very similar leaves in the Devonian beds of New South Wales and Victoria.

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[1] H. Gerth. "Geologie Südamerikas", Vol. I, p. 133, Berlin, (1932).

[2] A. Du Toit. "Our Wandering Continents," 70 (1937).

[3] B. Sahni. *Proc.* 13th *Ind. Sci. Congr.*, 242 (1926); A. Du Toit. *C. R. Congr., geol. internat.*, XV. 240 (1929).

Before leaving this aspect of the subject, mention may be made of some eurypterids, animal companions of typical members of the *Glossopteris* flora in the Brazilian Coal Measures and very similar to species found in the pre-*Glossopteris* rocks of South Africa.

Southern types in the Northern province.—As in the Southern, so also in the Northern province we find examples of admixture of the two types of vegetation, but here there is no question that the invaders came from the south. This irruption of members of the *Glossopteris* flora into the Northern province took place on an extensive scale and several portions of the old Angaraland show signs of this immigration. The normal Permian flora of Russia and Siberia shows, by the possession of many common types, its connection with western Europe and North America, but accompanying them in many widely scattered localities, members of the *Glossopteris* flora prove by their presence that there was some means of communication across the Tethys Sea during the latter part of the Palæozoic era. From northern Russia, through Siberia and northwest Mongolia to the Pacific coast, there is found this association of Northern and Southern types. Europe itself is not without these exotics and the four typical genera of the immigrant flora—*Glossopteris*, *Gangamopteris*, *Phyllotheca* and *Schizoneura*—are known to have been present in that continent in either Permian or Lower Mesozoic times.

The first found evidence of this northward migration was the now classical discovery of Amalitzky in the Upper Permian of the River Dwina of three species of *Glossopteris*, and of *Gangamopteris cyclopteroides*, side by side with species of *Callipteris* and other European forms, and all of them in association with remains of reptiles agreeing with Lower Karroo species in South Africa. Incidentally, this is the most northerly occurrence of the genus *Glossopteris*. Thus *Glossopteris* and *Gangamopteris* reached northern Russia before the close of the Permian period. Both persisted until Triassic times in Mexico, but the former survived and established itself in the Rhætic floras of Tonkin, southern Sweden and eastern Greenland; this is the highest geological horizon that *Glossopteris* is known with certainty to have attained. The Palæozoic genera, *Schizoneura*, *Phyllotheca* and *Neuropteridium*, by the Triassic period had spread as far as western Europe, while *Phyllotheca* survived until Lower Oolitic times in Italy. *Neuropteridium* and a *Schizoneura* very similar to an Indian species are found in the Bunter of the Vosges.[2] The *Glossopteris* flora died gradually in South Africa and possibly in South America, and in some places co-existed with a well developed Mesozoic flora; in Australia the change from one to the other was more abrupt. In India the glossopterids did not survive the Panchet.

Indo-China, Siam, Malaysia, perhaps a portion of Burma, and many of the East Indian islands, all formed a southeasterly extension of the Angara land-mass known as Cathaysia. The restricted Permian flora of central Sumatra is of purely

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[1] H. S. Rao. *Rec.*, LXIX, 171-172 (1935).

[2] Other genera more or less common to the two floras are *Odontopteris*, *Protoblechnum*, *Rhipidopsis* (*Journ. Ind. Bot. Soc.*, Vol. XV, 327 (1936)).

Northern type, with no trace of a *Glossopteris* element, seven out of the nine determined species being identical with or allied to well known European forms. Recently *Gigantopteris nicotinaefolia* Schenk, has been found in northern Laos. Tonkin has yielded a flora which is Northern in general character in spite of the reported occurrence therein of *Noeggerathiopsis*, two species of *Glossopteris* and *Palæovittaria hurzi* Feistm.; if these anomalous elements are not wrongly determined[1], they may be regarded as exotics in a Rhætic assemblage which is mainly of Northern type. Showing unmistakable affinities with this Tonkin flora and several identical species, is one collected by Coggin Brown at Miaotsway and Yunnan Hsien in Yunnan. Among them are *Tæniopteris jourdyi*, *Equisetites sarrani* and *Cycadites saldini*; in addition Sir Albert Seward has recognised a *Dictyophyllum* which may be *D. remauryi* or *D. fuchsi*, and a *Podozamites*—possibly *P. distans*.[2] Some eighty miles further to the northeast, the Coal Measure series exposed in the Yang-tze valley in northern Yunnan, in the neighbourhood of Chiu-ya-p'ing, Hsinkai, Hsing-chuang and Ma-ch'ang, composed of soft, grey sandstones, yellow or reddish-yellow shales, carbonaceous layers, coal seams and limestones, has been referred to the Rhætic on the evidence of its plant remains. From the roof of a coal seam at Tai-pin-ch'ang on the frontier of Yunnan and Ssu-Ch'uan, Zeiller has identified: *Cladophlebis roesserti* Presl., *Ctenopteris* sp., identical with an undescribed Tonkin species, *Tæniopteris* aff. *immersa* Nath., *Glossopteris indica* Schimp., *Dictyophyllum exuile* Brauns., *Clathropteris platyphylla* Göpp., *Pterophyllum* cf. *longifolium* Brongn., *Anomozamites inconstans* Brauns., and *Ptilophyllum acutifolium* Morr.[3]

There is an unconfirmed report of the occurrence of *Phyllotheca* and *Vertebraria* in the Sarawak coal measures of Borneo.[4] A more reliable case of immigrations however, is the occurrence in northern Laos—in the same locality and same beds which yielded the *Gigantopteris*—of *Schizoneura gondwanensis* Feistm.;[5] this form is associated with the Triassic plant, *Neuropteridium* aff. *polymorphum*, an association which seems to prove that one of the transient connections which appear to have united the Angara and Gondwana continents from time to time, especially in the Indo-Chinese region, was effected as early as Lower Triassic times.[6] *Glossopteris indica* is said to have been found at Tai-pin-chang (in Rhætic strata), north of Yunnan-Fu, in the east of Tonkin, in north Annam and in northern Haut-Laos.

Communication between the Northern and Southern continents.—In addition to plant evidence, there are other indications of connection from time to time between the northern and southern continents. The presence in south and central Africa of Russian species of the fresh-water *Palæomutela* is not the only example. Where such land connection was effected is not known and, it must be confessed, its existence is difficult to reconcile with the theory of continental drift. We are led to believe that communication between the northern and southern continents was effected long before the supposed drift of one towards the other, and existed during the greater part of the Palæzoic era; there are, for example, signs of inter-communication soon after the Talchir ice-age, an epoch during which we have visualised the as yet undismembered Gondwanaland-mass lying concentrated near the South Pole. As an example of the kind of discrepancy which presents itself, let us take the case of the *Gangamopteris* beds of Kashmir. These beds show distinct relationships with the Angara flora, a fact which led Dr. B. Sahni to suggest many years ago that Kashmir may have lain on one of the routes of migration from one continent to the other.[1] *Psygmophyllum*, a typically northern genus, well represented in the Angara flora, is abundant in the Kashmir beds; *Gangamopteris kashmirensis* is closely similar to the so-called "*Glossopteris angarica*" (which Sahni believes to be a *Gangamopteris*); and the fragmentary *Callipteridium* from the Golabgarh Pass has been compared by Sir Albert Seward to the northern Permian species *Callipteris conferta.* On the other hand, in the Salt Range only 120 miles away to the southwest, is the Talchir Boulder Bed with ice-scratched pebbles, which, according to the Drift theory, originated in much higher latitudes many thousands of miles further south in an epoch not very much earlier than that of the Kashmir plant beds. The Kashmir flora is a meagre one and, as Sahni himself remarks, its suggested affinity with that of Angaraland may be less close than it was at first imagined to be,[2] but that somewhere or other there was between the two great land masses a communication along which glossopterid plants found it possible to make their way is difficult to refute. Perhaps it lay between the Australian end of Gondwanaland and the Indo-Chinese peninsula of Angaraland (Cathaysia), a region of shifting gulfs and lagoons, geosynclines and anticlines, throughout a large part of the stratigraphical record. Further work will no doubt do much to reconcile discordances such as that instanced, and it may be that some of them are explicable on the assumption of earlier "drifts" than the one which has been so much under consideration.

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[1] B. Sahni found that in this collection "*Noeggerathiopsis hislopi*" at least was a wrong determination.

[2] *Gen. Rep. Rec.*, LXII, 26 (1929); *Ibid.*, LXV, 22 (1931).

[3] *C. R. Acad. Sci.*, CXXX, 186 (1900); J. Coggin Brown. *Rec.*, LIV, 331-2 (1922).

[4] *Nature*, XXXI, 583 (1885).

[5] M. J. Fromaget. *C. R. Acad. Sci.*, Vol. CXCVII, 341 (1933); J. Coggin Brown. *Rec.*, 71, 208 (1936).

[6] Other plants from these beds are: *Pecopteris hemitelioides*, *Cordaites* cf. *principalis*, *Phyllotheca* (?) cf. *deliquescens*, *Protoblechnum wongi* Fromaget. "Contrib. á l'étude structurale du sud-Est de l'Asie" (1934).

The Geography of Asia from Upper Carboniferous times to the end of the Trias.—The southern continent of Gondwanaland formed one of the most prominent features of the globe from Carboniferous to the end of Mesozoic times, but dated for the most part from a much earlier age. No doubt there were variations in temperature and climate in different parts of this vast land area, but conditions seem to have approached uniformly to an unusual degree and have been compared with those pertaining to the modern Greenland. The basal moraines of southeastern Australia are somewhat older than those of other parts of the continent, and their accumulation accompanied widespread and prolonged volcanic disturbances. In Australia, in fact, glaciation began in the Culm or Middle Carboniferous epoch, and after recurring four or five times disappeared finally towards the end of the Permian; the inter-glacial intervals denote a milder climate, especially that between glacial stages 4 and 5 during which an important series of Coal Measures were accumulated. The third of these Australian glacial epochs was the only one which seems to have affected the Indian area. The *Glossopteris* flora, which in some places appears to have arrived with the ice, flourished more abundantly during the long breaks between the icy spells and overran Gondwanaland throughout the Permian period.

The northeast coast of Gondwanaland seems to have followed more or less closely structural trend lines parallel to those which dominate this region today, and swung abruptly southwestwards and southwards from some point on the syntaxis north of Burma, curving round somewhere southwest of Sumatra and eastwards past Java to the northern margin of Australia and thence on to New Zealand. We have drawn this line to the southwest of Sumatra in spite of the reported but doubtful occurrence of a Talchir tillite on the east coast of Perak, lying upon a limtstone of Carboniferous age (Raub series), and situated, therefore, to the northeast of Sumatra ; the Permian flora of central Sumatra is predominantly Northern and a marine fauna of probably Lower Permian age occurs at Padang on the southwest coast of the island, facts which respectively indicate that the coastline which obviously traversed Sumatra about that time was that of the Cathaysian portion of Angaraland and that the Gondwana coast lay somewhere to the southwest of the present-day limits of Sumatra. We may also take the liberty of questioning the reported occurrence of tillites from Siam. This section of the Gondwana coast would have afforded means of intercommunication between the *Eurydesma*-containing sea of the Salt Range area and that of the Australian region at the close of the Carboniferous period (Uralian).[1]

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[1] *Proc. 13th. Ind. Sci. Congr.*, 240-241 (1926).

[2] "*Current Science*", IV, 387 (1935).

Of the northern coast of this southern continent in late Carboniferous and early Permian times we find indications in the Salt Range, Kashmir and the foothills of the Assam Himalaya, with a marine indentation extending to southern Rewah.

In Uralian times there was a widespread transgression of the sea over southeast Asia, and the communication of the Himalayan geo-syncline with the Mediterranean of Europe, if, as seems possible, it had been closed during the Moscovian epoch, was re-opened to permit an exchange of faunas from one end of Asia to the other. It extended over part of Burma into Tonkin, Laos and eastern Yunnan, up into central China and probably down into upper Siam and the East Indies, and across to western Australia. Along the southern shore of this Tethys Sea flourished a marine fauna which, although similar in general facies and composition to that which inhabited its deeper waters, exhibits minor individualities due to differences in environment and conditions of deposition.[2] The *Fusulina* and *Schwagerina* fauna of the deeper parts have been traced from central Asia, across Turkistan, Chitral and northern Afghanistan to Asia Minor, the Ural Mountains and European Russia. Thus the only fusulinids known in the Salt Range, *Fusulina longissima* Möll., *F. kattaensis* Schw., and *F. pailensis* Schw., are found throughout almost the whole of eastern Asia, the first being, besides, very abundant in Russia.[3] Similar great masses of *Fusulina* limestone occur in Turkistan and in the Southern Pamir, corresponding to the *Schwagerina* and *Lithostrotion* limestones of the Persia-Armenia border country. The Upper Carboniferous in its marine facies has been identified in the Kuen Lun range, and recognised in disturbed and fragmentary patches in the Tian Shan, but appears to be absent in Siberia. The southern shore of the Tethys was the scene of great volcanic activity, commencing before the close of the Upper Carboniferous epoch and continuing until Triassic and perhaps in places still later times.

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[1] According to Du Toit, the presence of the New South Wales *Eurydesma* fauna in South-West Africa, as well as that of the *Stuchpuria* fauna in Southern Brazil, is due to the migration west-wards along the "Samfrall geosyncline", a depression stretching from Eastern Australia across to the lip of South Africa and thence to Argentina.

[2] *Pal. Ind.* Vol. VI, Mem. New. Ser., No. 4, 131 (1925).

[3] M. Fromaget. " Contrib. a l'etude structurale du Sud-Est de l' Asie," (1934).

As we have seen, there are strikingly close resemblances between the early Upper Carboniferous fauna of the Salt Range and that of New South Wales, indicating probably a continuous coast from one area to the other. During the Lower Permian, the Pacific element including that of Western Australia, is still the strongest outside feature in the fauna of the Salt Range (Lower Productus Limestone), according to Dr. Cowper Reed[1] though the Boreal is present in a much smaller degree. At the end of the Lower Permian, however, a marked change is seen in the fauna of this area, due either to the removal of some barrier or obstacle or merely to the successful advance of Boreal forms. The resemblance to Australia has ceased and is replaced by Boreal affinities. To the Russian Ural area of deposition the Salt Range shows a very close relation during the Middle and Upper Permian epochs, a much closer affinity than it does to any other part of Europe or to any part of Asia or America. In the Middle and Upper Productus faunas (Middle and Upper Permian) it is the Boreal element, and especially that part of it developed in the Urals, which is prominent. The Western or European element is described as scarcely noticeable, while only a few North and South American representatives of the Pacific element are present. Dr. Reed concludes that in the Middle and Upper Productus Limestone the autogenous element is more strongly marked and the number of peculiar local species exceeds all others.

The above change may have been due to some alteration in climate which encouraged the immigration of Boreal forms. Nevertheless, the Productus Limestone fauna of the Punjab can be closely matched among the rich Permian collections from the East Indian islands of Rotti and Timor ; common to the two regions there are no less than eleven forms. The Plateau Limestone of north Burma contains one or two assemblages which appear to be of Lower Permian age ; it has also yielded a fauna exceedingly close to that of the Salt Range Middle Productus Limestone (Middle Permian), and close to that of corresponding beds in the Himalaya, while the Moulmein Limestone of south Burma not only shows relationships with these Salt Range beds but also contains *Schwagerina*. A fauna with Productus Limestone affinities has been found in western Persia.

Dr. Cowper Reed is of opinion that the Tethys could not have been a continuous sea during the whole Permian period, but must have extended in various directions and have been divided occasionally into more or less distinct basins or arms resulting in the development of local species, especially in the Salt Range area. With its Zewan beds and Productus Shales, nevertheless, it remained the channel of communication between Europe and the Chinese basin by way of the Kuen, Lun region, Turkistan, Persia, Armenia and Asia Minor, throughout most of the Permian period. Besides a large part of Burma, the Middle Permian sea also covered Yunnan, most of Indo-China where the whole system is well developed, probably parts of Siam, the southwestern edge of Sumatra, Rotti, Timor and other East Indian Islands.

During the warmer and drier climate of the Trias or Panchet, the *Glossopteris* flora dwindled and faded and probably did not survive this period in India ; in New Zealand and Tasmania one or two relics of it persisted and in various parts of the northern continent a few of these foreign plants co-existed with a well developed Mesozoic vegetation. The widespread advent of desert conditions seems to have been responsible for a crisis in plant evolution during the Lower Trias, and the initiation of the " *Thinnfeldia* flora " of the Upper Trias and Rhætic. This change in flora was characterised by a return to the uniformity which had prevailed over the world in Upper Devonian and Lower Carboniferous times. There is little difference between the Mesozoic floras of the Northern and Southern provinces, and the Upper Gondwana plants differ in no marked features from their contemporaries in Angaraland. The Jabalpur and Umia floras, for example, show a much greater definiteness of relationship to European floras of the same age. There are at the same time in the Mesozoic floras signs of the same adaptability to great differences in temperature and climate ; the Jurassic flora of Graham Land, for instance, close to the Antarctic Circle, includes several species identical with Upper Gondwana plants from India as well as with Jurassic forms from the Yorkshire coast.[1]

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[1] *Pal. Ind.* New. Ser. XXIII, Mem. 2, 375 (1943).

In Triassic times we find the remains of reptiles, and to a lesser degree of amphibians, scattered all over the various relics of the Gondwana continent. In South Africa especially their bones form an illuminating chapter in vertebrate evolution. Throughout the rest of the Mesozoic these types lingered on until the vast volcanic disturbances of the Deccan Trap and its homologues, during which they seem to have perished. The later history of the Gondwana continent will be considered in later chapters ; at this stage it is only necessary to point out that even in the igneous rocks, both intrusive and effusive, we find the same resemblances and uniformity in the various surviving sections of this ancient land-mass. The peridotites of Darjeeling, Raniganj, Jharia, Giridih, Deogarh and Ramgarh are closely paralleled by the diamond-bearing peridotite of South Africa which intrudes carbonaceous beds of about the same age as the Damuda (Ecca beds and Kimberley shale) ; in addition are the basaltic dykes, the effusive representatives of which are seen capping the Stormberg sedimentaries and thus occupying a position equivalent to the Rajmahal traps of Bengal.

From the beginning to the end of the Triassic period, the general configuration of the Asiatic region seems to have suffered very little change. The close of the Permian was marked by the formation of a complex system of mountain ranges over large tracts of the Angara continent which, with the great land-mass of Cathaysia to the southeast, made up what Grabau has termed the land of Pal-Asia. A long arm of the sea, known as the " Ussuri Gulf," stretched southwards into Angaraland from the Boreal regions to the neighbourhood of Vladivostok. At the end of the Permian period, while the Mongolian geo-syncline was being drained, the Tethys Sea might have retreated for a time from the Himalayan and Salt Range regions and, although it returned during the Lower Triassic epoch, sedimentation was reduced to about 100 feet in the Himalaya and about twice that thickness in the Salt Range, as compared with nearly 3,300 feet in the Alps and over 5,000 feet—nearly half being limestone—in Idaho. Throughout the Trias, the Himalayan geosyncline remained as part of the Tethys Sea and maintained its connection with Europe. Eastwards it covered southern China and sent a northerly arm over the Yung-ling geosyncline, curving round the eastern borders of Tibet. There is evidence to show that the southern shore of the Angara continent which lay to the north of the Tethys shifted appreciably towards the south after the close of the Permian period. It is possible that sedimentation in the Himalayan region suffered local interruptions from time to time, but the sections give no impression of unconformity, and gaps in the faunal sequence may have been due partly to obliteration of organic remains subsequent to their accumulation, and partly to periods of non-deposition.

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[1] A. C. Seward. *Q. J. G. S.*, LXXX, xcii (1924.)

In Europe two types of deposits were being laid down during the Lower and Upper epochs of the Trias in two separate basins, the northern mainly continental and the southern or Alpine typically marine ; during the Middle epoch these two basins became united along the line of the Rhine and deposition was of a marine type in both areas. It was the Alpine basin which formed part of the Tethys and extended eastwards across Caucasia, Armenia and Persia, northwest India and the Himalaya to China where the facies of the deposits is described by Grabau as marginal and of a shallow water character.[1] The Triassic faunas of the Afghanistan-Bokhara frontier (Darwaz), Asia Minor and the Caucasus are closer to those of the Alps than to the Himalaya.[2] Farther west, the Alpine fauna is linked, at any rate during the Upper epoch of the Triassic period, with that of Siberia by the faunas of the Crimea and the Caucasus. In spite of local characteristics which distinguish it from that of the Mediterranean, the Triassic fauna of that part of the Tethys which covered the Salt Range, the Pamirs, the Himalaya, and parts of Burma, Yunnan, China proper, Indo-China and the Malaya Archipelago, bears evidence of some connection with that region.

Throughout all but perhaps the earliest part of the Triassic period, the eastern end of the Tethys seems to have been connected with the Indian and Pacific oceans by way of a channel skirting the western and southern shores of Cathaysia. The small Triassic fauna found in Singapore and Pahang, although including no forms completely identical with those of the Himalayan Trias, and only one (*Modiolopsis gonoides* Healey) from the Rhætic (Napeng) beds of Burma, shows specific connections with the Trias of Europe, especially with the St. Cassian beds of the Tyrol.[3] Similar affinities are shown by the Triassic faunas of Indo-China. The assumption of the presence of this channel is necessary in the opinion of Dr. Grabau to explain the presence of the *Ceratites* [*Paraceratites*] of the Lower Trias in the eastern Tethys. These could not have been derived from the Atlantic since the western Tethys was replaced by basins with continental sedimentation. Nor is the evidence in favour of all of them having originated in the Boreal province, " for those found in the deposits of the northern waters differ specifically, and often generically, from those which characterised the southern deposits ". In support of this contention is the presence of the cephalopod genera, *Danubites*, *Columbites*, and *Inyoites*, characteristic of the Pacific American Lower Trias, associated with *Pseudomonotis griesbachi*, a lamellibranch found in the lowest Trias of the Shalshal cliff of Painkhanda, in some shales in eastern Tonkin. This is practically the only suggestion of the existence of Lower Trias beds in Indo-China, though early Middle Triassic faunas are known to occur in these parts ; in fact, most of Yunnan and Indo-China, during the Upper Permian and probably also most of the Lower Triassic epoch, was exposed to erosion. The American affinities of the Indian Lower Trias have perhaps been exaggerated.

In the island of Timor there are several different facies of the Trias, representing simultaneous periods of deposition under widely different conditions.[4] In the

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[1] "Stratigraphy of China", Pt. II, 6 (1928).

[2] C. Diener. *Mem.* XXXVI, 347 (1912).

[3] R. B. Newton. *Proc. Malac. Soc.* IV, 134 (1900) ; *Geol. Mag.*, 487-496 (1906) ; *Ann. Mag. Nat. Hist.*, Ser. 9, XII, 300-321 (1923) ; L. R. Cox. *Ibid.*, Ser. 10, XVII, 213-220 (1936).

[4] H. Brouwer. " Geology of the Netherland East Indies", 18-24 (1935).

Lower Trias both the "*Otoceras*" and "*Meekoceras*" zones of the Himalaya are present, and with these two genera is associated *Ophiceras*. Professor Brouwer correlates the Owenites Limestone, which, unlike the "*Meekoceras*" limestones of the island, includes numerous American types, with the Hedenstrœmia beds of the Himalaya and with the Ceratite Sandstone and perhaps the Upper Ceratite Limestone of the Salt Range. The Sibirites Limestone of Timor evidently corresponds to the zone of *Sibirites spiniger* in Byans, and is considered by Brouwer to be the probable equivalent of the upper part of the Upper Ceratite Limestone of the Salt Range.

Various points are explicable on the assumption that in early Triassic times some corner of Gondwanaland became united, temporarily at any rate, with the main mass of Angaraland perhaps by way of the Cathaysian peninsula ; perhaps such a union would account for the cosmopolitan character of the Triassic flora. The absence of *Glossopteris* in Burma is due to the fact that the greater part of that country lay beneath the ocean at that time ; elements of that flora, however, are found in definitely recognisable parts of Cathaysia.

The confines of Cathaysia are indicated in a general way by the trend of the East Indian Islands, its coast sweeping southwards and curving eastwards, parallel to the present shores of Sumatra and Java. Omitting the several gulfs which pierced it at various epochs of the Trias, Cathaysia thus embraced at one time or another much of Yunnan and Indo-China. It was a region of geosynclinal folds, and its local vacillations from continental to shallow marine conditions make the correlation of its Mesozoic components difficult. According to M. Fromaget, Cathaysia was separated from the land to the north in Triassic times by a four-branched gulf which debouched into the southern ocean across the Kamawkala area of southern Burma. The most westerly of these branches is drawn as extending northwards through Yunnan into western China.[1]

In the Amherst district of Burma, only the Upper Trias (Carnic or Noric) has been recognised. In the western parts of Yunnan no marine facies of the Lower Trias has been identified, and the Middle stage is but poorly represented ; in Eastern Yunnan are found the Lower and a considerable development of the Middle Trias. The most widespread stage in Yunnan is the Upper Ladinian. In Indo-China, besides the beds with a fauna suggestive of the Lowest Trias, early Anisian beds are known, but the most extensively distributed divisions are the Upper Ladinian and Lower Carnic ; the latter, represented in the Himalaya by the zone of *Joannites cymbiformis*, includes many of the species or their close allies found in the St. Cassian beds of the Alps. Over the greater part of Indo-China the Norie has a lagoonal facies, consisting of red earth with salt and gypsum and in places a flora which includes exotic specimens of *Glossopteris indica ;* in the eastern parts of the Haut Laos marine beds with *Anodontophora münsteri* Wissm. are found at the base of this stage. In western Borneo the Triassic period begins with the Noric, in northern Sumatra with the Carnic[2], while in Timor, on the other hand, there is a more complete marine sequence, as in the Himalaya, from the Lower to the Upper Trias. The Upper Trias of the Sunda Islands (Nucula Marls) and of Sumatra (Padang beds) is described as of somewhat similar character to that of Yunnan.

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[1] *Bull. Serv. géol. Indo-Chine*, XVIII, Fasc. 5, map apposed to p. 16 (1929) ; see also "Contribution à l'étude structurale du Sud-Est de l'Asie" by the same author (1934).

[2] J. W. Gregory. *Rec.* LXIII, 158 (1930).

As a whole, the Upper Trias of the Malay Archipelago, exposed in the islands of Rotti, Sumatra, the Sundas, Borneo, Timor, Serang, Savu and Misol, as well as that of Tonkin, Annam and the Laos States of Indo-China, belongs to the Himalayan province but forms a connecting link between this region and the Pacific; uninterrupted connection between the Tethys and the Pacific, for some part of the period at least, is thought to be confirmed by the Indian and even Mediterranean element in the Triassic faunas of New Caledonia,[1] and the character of the New Zealand Trias.

On the Arctic island of Kotelny in New Siberia, the Carnic Stage is represented by shales and marly limestones with Halobiæ of Indian affinities; cephalopods are rare and are limited mainly to species of *Cladiscites*, *Pinacoceras* and *Arcestes*. In California, the Carnic stage is present in the form of the Tropites beds which, although having species in common with Himalayan forms, show much closer faunistic affinities with the Mediterranean equivalents.

The recent discovery of what is probably the lowest zone of the marine Lower Trias above the Plateau Limestone of the Northern Shan States indicates that the reefs of the Devonian, Carboniferous and Permian lingered on, in some places at any rate, into the oldest epoch of the Trias.

In the Noric epoch, the earlier deeper-water sedimentation in Cathaysia was replaced by deposits of shallow-water type, accompanied by a still further encroachment upon the land. The retreat of the sea from the gulfs led to deposition under swampy and lagoonal conditions, as indicated by coal seams and beds of salt and gypsum. Elsewhere, in depressed areas, continental degradation gave rise to vast accumulations of epicontinental red beds. In Dr. Coggin Brown's opinion, the earliest date of the latter probably varies considerably from place to place; over large tracts of this interesting region they began perhaps as early as late Permian, were well established during the Trias, and continued through the Jurassic into the Cretaceous and Tertiary. Diener notes that the exchange of faunistic elements between America and the Himalaya appears to have been suspended entirely during the Noric epoch, for the affinities between the two faunas are very remote. The *Pseudomonotis ochotica* fauna (? *P. subcircularis*), widely distributed in northern Asia and along both coasts of the Pacific, reached neither India nor the region of the Alps.[2]

Among the many Triassic exposures in Persia, one from the southern border of Kuhistan, belonging to the Upper Trias and probably to the Noric, has yielded a small fauna which includes *Pecten* (*Indopecten*) *clignetti* Krumb. and a species of *Heterastridium*, the curious hydrozoon which is so abundant in the Kioto Limestone below the Karakoram Pass and in the Upper Trias of Timor.[3] A very similar but more meagre fauna of the same age has for a long time been known to occur in a limestone approximating to the Kioto Limestone and exposed in the Elphinstone Inlet of the Oman peninsula of Arabia[4]; this fauna has lately been added to and summarised by Dr. G. M. Lees[5], and includes: *Myophoria omanica* Dien., allied to *M. chenopus* Laube of the Alpine St. Cassian beds; *Pecten* (*Indopecten*) *clignetti*

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[1] C. Diener. *Mem.* XXXVI, 356 (1912).

[2] *Mem.* XXXVI, 315 (1912).

[3] J. A. Douglas. *Q. J. G. S.* LXXXV, 628 (1929).

[4] W. T. Blanford. *Rec.* VI, 76 (1872); C. Diener. *Ibid.* XXXVI, 156 (1907).

[5] ***Q. J. G. S.***, LXXXIV, 634—638 (1928).

Krumb., common in the East Indies ; *Lima subcamaunica* Krumb., another East Indian form very close to *L. camaunica* of the Himalayan Noric ; and *Lima* (*Plagiostoma*) *subvaloniensis* Krumb., yet another species found in the East Indian Archipelago.

The above Persian fauna and the scanty assemblage from Oman have little in common with either the Himalayan, Kashmir or European faunas but, curiously enough, show unmistakable indications of belonging to the same zoological province as the Noric faunas of the East Indian islands. There seems little doubt, therefore, that they bridge, in however an imperfect way—due perhaps to shallower conditions—the gap between the Triassic exposures of Asia Minor on the one side and Baluchistan and Afghanistan on the other. A littoral facies of the Trias near the Dead Sea suggests a shore-line in the immediate vicinity, but whether this belongs to the Carnic or to the Lower Trias is not certain.[1]

Marine Triassic deposits have not been observed along the east coast of Peninsular India, and there is, therefore, no positive evidence that what is now the Bay of Bengal was a sea area and not part of the Gondwana continent during the Triassic period. The supposed Triassic deposits of the Arakan Yoma, including as they do coarse sandstones, grits and conglomerates of a coastal nature, would have justified the suggestion that the Gondwana shore-line lay along the Arakan Yoma region and that continuous land stretched thence across to what is now the Indian peninsula. As already stated, however, there are serious doubts as to the identification of these beds in the Yoma, and all that can be said is that the highly fossiliferous, pelagic facies of the Trias, so abundantly found further to the east in Yunnan and Indo-China, does not, at any rate, appear to be represented in the Yoma. Until the latter mountain belt is more thoroughly surveyed, it is impossible to form an opinion as to whether the Bay of Bengal had or had not been formed by Triassic times.

Marine Triassic deposits have failed to be observed in either the eastern or southern portions of the African continent, and the bathymetric configuration of the western half of the Indian Ocean tempts one to assume that the Gondwana coast-line extended from Ceylon southwestwards through the Chagos group to the Mascarenes and beyond in the general direction of Madagascar and the Cape. A rich cephalopod fauna of Lower Triassic age has, however, been found in the north of Madagascar, and we must deduce an indentation, either northwards from the southern ocean, or southwards from the Tethys, as far as the northern point of Madagascar. A northward prolongation of the southern ocean would be the shorter of the two but for two reasons the alternative is the more probable. In the first place, we know that there was a southerly branch of the Tethys along what is now the east coast of Africa in the following Jurassic period and there may have been a forerunner of this in early Triassic times. Secondly, the fauna is a particularly clear repetition of the Himalayan and Salt Range faunas of the same age, and has close affinities with that of Idaho. The following are provisional determinations of the interesting fauna in these beds which are superposed on the Permian and crystallines :[2]

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[1] L. R. Cox. *Ann. Mag. Nat. Hist.*, Ser. 10, X, 101 (1932).

[2] M. Collignon. *C. R. Acad., Sci. Paris*, CXCVII, 993-994 (1933).

Cephalopoda—

Orthoceras aff. *dubium* v. Hau.,

Nautilus kieslingeri Coll.,

Ophiceras (*Gyronites*) *frequens* Waag. (a Salt Range form),

Vishnuites sp. (a rare genus typical of the Himalayan Lower Trias),

Flemingites spp. (several species close to forms in the Ceratite beds of the Salt Range or the Hedenstrœmia beds of the Himalaya, such as *F. radiatus*, *F. flemingianus*, *F. compressus*, *F. griesbachi;* also a Timor species, *F. pulcher*),

"*Meekoceras*" spp. (a few species, including "*M.*" (*Proptychites*) *markhami* which is so abundant in the Shalshal cliff of Painkhanda, "*M.*" *Pseudoplanulatum*, a Spiti form, and "*M.*" aff. (*Xenodiscoides*) *falcatum and* "*M.*" (*Proptychites*) *khurense*, both found in the Salt Range),

"*Aspidites*" (including *Kingites*, *Koninckites* and *Clypeoceras*) spp. (numerous examples, including *Koninckites haydeni* (v Krafft), and *A.* ("*Meekoceras*") *ensanus* (v. Krafft), two Spiti species, and some new forms akin to other Himalayan species).

Hedenstroemia mojsisovicsi Dien. (the only species; but very abundant—a Spiti species).

Pseudosageceras multilobatum Noetl. (the only species but numerous found in Spiti and the Salt Range),

Paranannites sp. nov. (a genus found in Idaho and Albania),

Proptychites aff. *typicus* v. Krafft (a Himalayan form; some new species also),

Juvenites sp. nov.

The northern coast of Gondwanaland coincided approximately with the Himalayan belt and here again there is evidence of slow, gradual depression, accompanied by marine transgression in a southerly direction. The lower beds of the Kuling system are shallow-water coastal deposits, while the upper are shales with a brachiopod fauna; the calcareous element increases from below upward, and the succeeding Trias consists chiefly of limestone, most of it of a pelagic character, very little mixed with terrigenous sands and muds, and containing a deep-sea cephalopod fauna. What is now the frontier region of India and Tibet was, during the Permian and Triassic periods, a subsiding sea-bottom in front of a slowly receding shore. Slow subsidence was replaced by slow upheaval in Liassic times, but deposition, though perhaps interrupted from time to time, seems to have been unmarked by sudden changes from the latter part of the Palæozoic to well past the middle of the Mesozoic.

CHAPTER XXV.

THE MARINE JURASSIC AND SOME EQUIVALENTS.

Peninsula margin. **Cutch** ; Authorities ; Exposure and structure ; Thickness and relationship ; Subdivision. The Lower Pachham ; The Upper Pachham ; The Chari series ; The Golden Oolite ; Rehmanni stage ; Anceps stage ; Athleta stage ; The Dhosa Oolite ; Katrol series ; Kantkot Sandstones ; Jurun Beds ; Lower Katrol stage ; Middle Katrol stage ; Upper Katrol stage or Gajansar Beds ; The Zamia Shales of Narha ; Umia series. Kathiawar and Baroda. **Rajputana :** General succession ; Jaisalmer Limestone ; Badesar Sandstones ; Parihar Sandstones. **The Salt range. Trans-Indus continuation of the Salt Range. Baluchistan :** Position and distribution ; Subdivision and relationships ; Lias ; Bajocian and Bathonian ; Callovian of Mazar Drik ; Tithonian. **The Sulaiman Range. Southern Waziristan. Tochi valley. Northern Kohat. Peshawar district. Bara valley. Tirah. Spiti, Garhwal and Kumaon.** Kioto Limestone ; Beds between the Kioto Limestone and Spiti Shales, including the Sulcacutus Beds ; Spiti Shales. **Nepal. Exotic Blocks of Malla Johar. Tibet** ; Distribution and general character ; Mount Everest region ; Tsang and U ; Ngari Khorsum ; Central Tibet. **Kashmir :** Punch Jurassics ; Tagling Limestone ; Karakoram area : Kashmir district. **Hazara. Attock. Chitral and the Pamirs :** Chitral ; Pamirs. **Madhan Slates of the Simla area. The Tal series of Sirmur and Garhwal. The Napeng and the Namyau formations of Burma :** Age ; **The Napeng stage ; Hsipaw, Northern Shan States :** Introduction ; Lithological characters ; Distribution ; Mode of accumulation ; Fauna ; **North Hsenwi ; Upper Yangtze-kiang valley. Namyau series : Hsipaw State :** Relationships ; Distribution ; Lithological character ; Physiography ; Thickness ; Fauna. **The Loi-an series and Kalaw Red Beds of the Southern Shan States. The Red Beds of Southern Burma. Representatives of the Loi-an and Kalaw beds in Meiktila and the Northern Shan States. Age of the Red Beds of Southeastern Asia. Palæogeography.**

Peninsula Margin.—The Peninsular region is devoid of marine beds of Jurassic age except in two marginal tracts, one situated southeast of the Indus delta where a large and important development of these rocks occurs in the " island " of Cutch (Kachh), the other in western Rajputana some 150 miles northwest of the Aravalli axis.

CUTCH.

Authorities.—Our information regarding the stratigraphy of the Cutch Jurassic is derived from a memoir by Mr. A. B. Wynne[1], supplemented by field notes made by Mr. J. H. Smith of Bhuj and Dr. Raj Nath. The indefatigable labours of Mr. Smith have resulted in an extensive addition to our collections of Cutch fossils. An exhaustive study of the cephalopoda collected by Mr. Smith and others, including a revision of Waagen's monograph, has been made by Dr. L. F. Spath, whose important palaeontological memoir includes the consideration of some 6,600 specimens, made up of 114 genera and over 600 species and varieties[2].

Exposure and Structure.—The Jurassic area of Cutch, one of the Federated States of Western India, occupies a number of post-Tertiary " islands " now connected by alluvial flats and lying in the salt, marshy " Rann of Cutch ", which is a former sea basin now in process of being filled up by silt. The rocks

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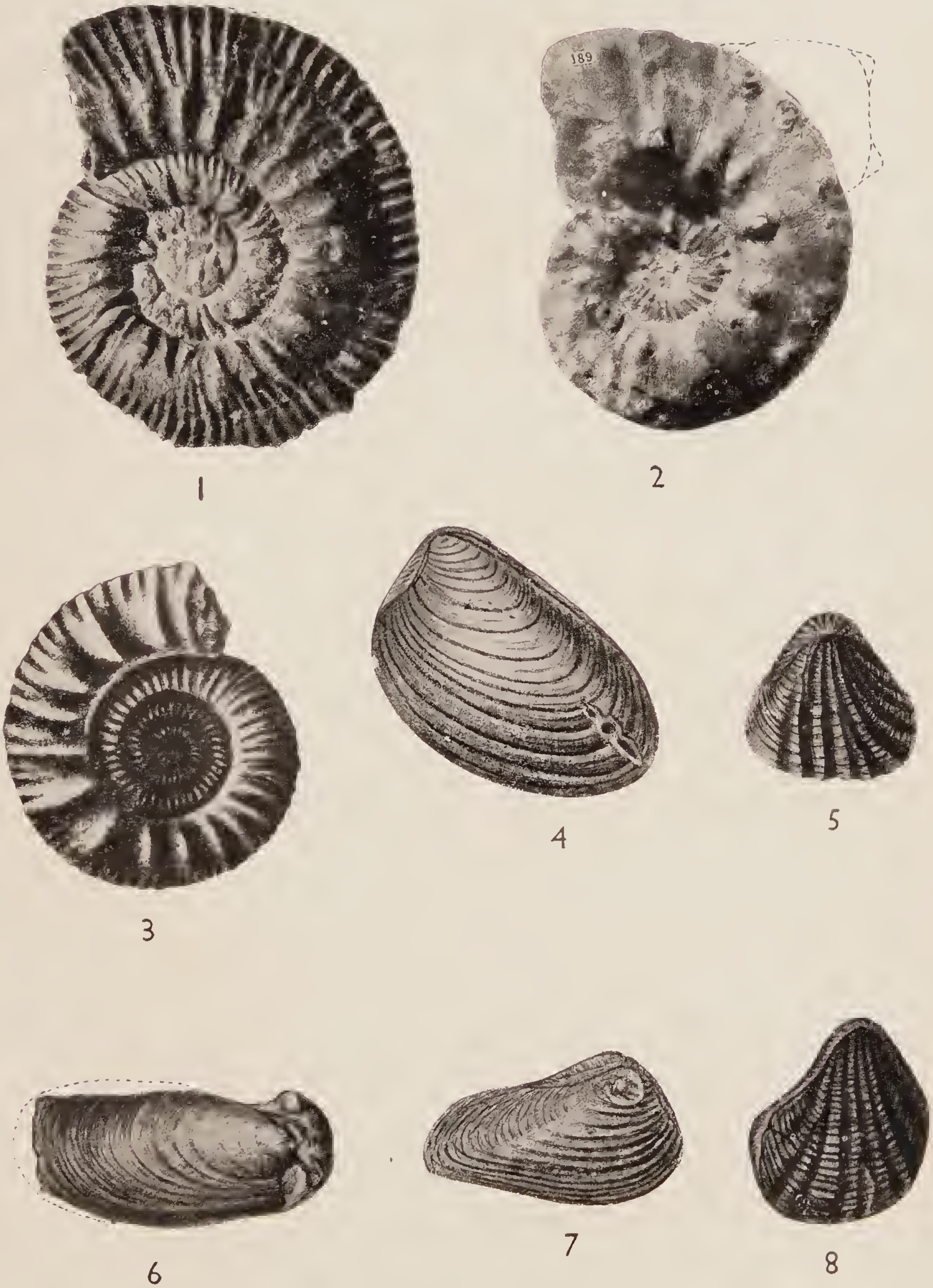
[1] *Mem.* IX, Art. 1, (1872).

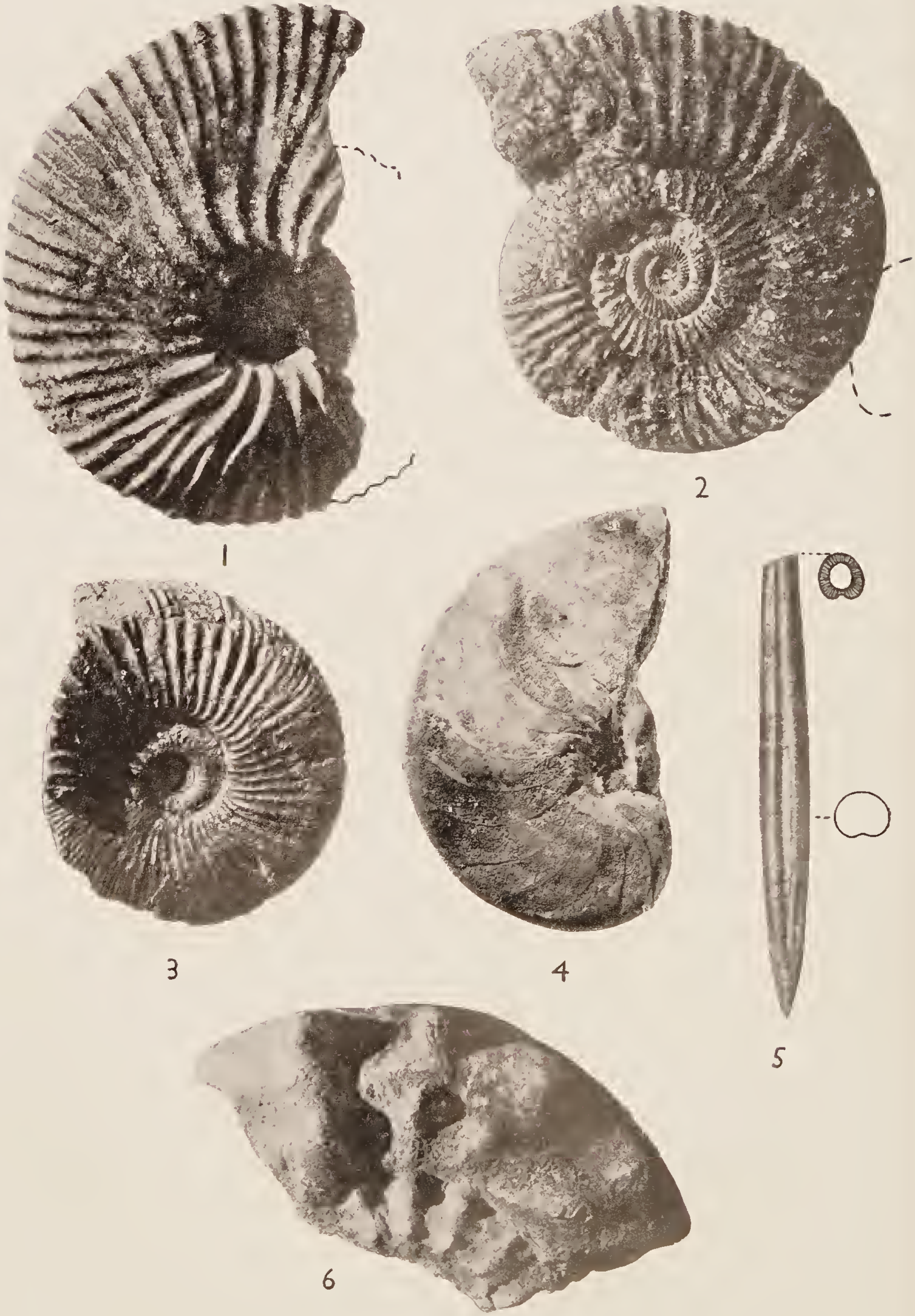
[2] *Pal. Ind.*, New Ser., IX, Mem. 2 (1927-8, 1933).



JURASSIC FAUNA (A).

1. *Reineckeia* cf. *reissi* Stein. 2. *Euaspidoceras waageni* Spath. 3. *A.* (*Perisphinctes*) *pottingeri* Sow. 4. *Astarte major* Sow. 5. *Pholadomya angulata* Sow. 6. *Aucella leguminosa* Stol. 7. *Trigonia smeei* Sow. 8. *Pholadomya granosa* Sow.

G. S. I., Calcutta.



JURASSIC FAUNA (B).

1. *Indocephalites chrysoolithicus* (Waag). 2. *Torquatisphinctes torquatus* (Sow). 3, *Subkossmatia opis* (Sow). 4. *Paracenoceras* cf *kumagunense* (Waag). 5. *Belemnopsis grantana* (d'Orb). 6. *Peltoceras kachhense* Spath.

G. S. I., Calcutta.

of Cutch, none of them older than Jurassic, crop out in three anticlinal hill ranges and an isolated mass to the east of less simple structure and known as Wagur (Wagad). The northernmost range, nearly 100 miles long and composed chiefly of Lower Jurassic sediments, is broken up into four " islands " which, from west to east, are Pachham (Patcham ; Putchum), Khadir (Kharir, Khurreer, Karrir or Kurreer), Bela and Chorar. The median range, which is by far the most important and occupies the northern margin of the main island of Cutch proper, forms a gentle arc, extending from the town of Lakhpat (Lukput) southeastwards and eastwards for 120 miles. The eastern end of this range is separated by a plain from another ancient island lying to the northeast, which is nearly 50 miles from west to east and 25 miles across, and forms the district of Wagur or Eastern Cutch. The strike of the Wagur rocks is continuous neither with that of the northern nor with that of the median range, but is intermediate between the two ; according to Wynne's suggestion the continuation of the Wagur rocks is concealed beneath the silts of the Rann. The most southerly of the ranges centres in the Charwar and Katrol hills, south of Bhuj, the capital of Cutch, and extends for about 40 miles roughly parallel to the central portion of the median range. The median and southern ranges of the main " island " form one continuous outcrop of Jurassic and younger rocks, some 40 miles across its maximum width. The three anticlinal ranges mentioned above are broken up by transverse undulations into a number of domes, the erosion of which has exposed successive beds in a concentric series of small scarps which, as Dr. Spath remarks, would seem to afford an ideal opportunity to the fossil collector. Between the median anticline and that of the Katrol-Charwar range, signs of flat dome structures are not wanting as, for instance, that observable near Chhota Rudra Mata. The syncline between the northern and median anticlines lies buried for the most part beneath the silts of the Rann. The northern limbs of all the folds are considerably steeper than the southern, and contortion is occasionally seen. Along the northern base of the Katrol-Charwar range Wynne locates a fault of considerable magnitude but his estimated throw of 2,000 or 3,000 feet may be too high. A few islands smaller than those already mentioned also occur, but none of them is of sufficient size to be worthy of notice.

Thickness and Relationships.—The total thickness of the Mesozoic rocks of Cutch has been estimated by Wynne to be 6,300 feet of which 3,000 feet, or very nearly half, belong to the uppermost of the four groups into which Stoliczka divided the succession. It must be remembered, however, that the base, though inferred to rest upon the metamorphic rocks of which a portion crops out in the vicinity at Nagar Parkar on the north side of the Rann is not exposed in Cutch, and also that the beds had suffered denudation before they were covered by the Deccan Traps. In the island of Bela and elsewhere some of the lower beds contain a few rolled pebbles of metamorphic rocks, but in scanty numbers only. In general the higher Jurassic beds disappear to the south beneath the Deccan Traps, but marine Tertiary beds (Nummulitic), in many parts of the country overlap the traps and rest upon the older rocks, both traps and nummulitic beds being quite unconformable to the Jurassic subdivisions. In one spot some limestones containing Cretaceous cephalopods are found resting upon the Jurassic beds.

Subdivision.—Excluding the Cretaceous beds at Ukra, just mentioned the Mesozoic beds of Cutch have been subdivided into the following four groups.

the three lower are largely argillaceous and entirely marine, while the uppermost, which is composed of coarser deposits, includes a fresh-water plant-bearing stage intercalated between beds with marine fossils:

	Synopsis of the Cutch Mesozoic Succession.		No. of species and varieties of cephalopoda.		
Ukra Beds.					Aptian.
Umia series	Sandstones and shales with plant remains and a few marine fossils. Unfossiliferous shales. Trigonia sandstones. Oolitic sandstones, shales and conglomerates, with marine fossils.		17		? Purbeckian to Neocomian. Portlandian.
Katrol series	5. Katrol sandstone (unfossiliferous). Gudjinsir bed (marine fossils), Zamia shales.		22		
	4. Brown and red ironstones		68	? Upper	Kimmeridgian.
	3. Basal Ammonite bed		67	Middle	
	2. Jurun Belemnite marls		10	? Lower	
	1. Kantkot Sandstone		53		Argovian.
Chari series	5. Dhosa Oolite	Upper	7		
		Lower	80		Divesian.
	4. Athleta stage	Upper	41		
		Lower	87		
	3. Anceps stage	Upper	53		Callovian.
		Lower	61		
	2. Rehmanni stage		48		
	1. Golden Oolite	Upper Macrocephalus beds.	47		
		Middle Macrocephalus beds.	25		Bathonian.
Pachhim series	2. Upper stage, or Lower Macrocephalus beds.		11		
	1. Lower stage		7		

The Lower Pachham.—The lowest beds of the Pachham series, so named after the island in the Rann, are exposed along the northern scarp of what we have alluded to as the northern range, the rocks dipping south at a low angle. The crest of the hills and the surface of their southern slopes are formed of a thick, massive bed of yellowish sandstone and limestone often crowded with specimens of *Corbula lyrata* Sow. and *Trigonia pullus* Sow.;[1] *Astarte, Cucullaea* and other fossils also occur and a belemnite doubtfully assigned to *Megateuthis* may have come from this horizon. Below the massive bed come shales and sandstones, all more or less calcareous, containing *Lima*, *Gervillia*, a *Rhynchonella*[1], a small *Exogyra*, etc. The lowest bed seen in Pachham island is a calcareous sandstone abounding in the small *Exogyra*. The Lower Pachham beds are again seen in the small islet of Koari Bet northwest of Pachham, and on the northern flank of the hill range in Khadir, Bela and Chorar, the crest of the range in all cases consisting of the yellaw calcareous rock. The thickness of this part of the series is at least 500 feet.

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[1] The specific determination of the lamellibranchs never seems to have reached more than the provisional stage. The 2nd. Edition of this Manual mentions *Corbula pectinata, Astarte compressa, Cucullaea virgata* and *Trigonia* cf .*interlaevigata* as being "in all probability correctly determined", but confirmation is desirable (*See*, for instance, Dr. F.L. Kitchin., *Pal. Ind.* Ser. IX, Vol. III, Pt. II, No. 1, p. 5).

The Upper Pachham.—The upper division of the Pachhams comprises light grey or yellowish limestones and marls and at the top, very compact, white limestones with shale intercalations. Besides forming the range of hills in the islands of the Rann, it is exposed at four places along the northern edge of the main province of Cutch, *viz.* at Jarra, Kira hill near Chari, Jura hill and Halaman hill near Lodai. In all these places it forms crestal inliers of anticlinal domes surrounded on all sides by younger beds. The white limestones are best exposed at Jarra, some 50 miles northwest of Bhuj, where they are overlain by the Chari series.

The lower part of the Upper Pachham division is especially rich in corals some 66 species and varieties, most of them from a locality northwest of Jumara, having been determined by Professor J. W. Gregory[2] ; among them are four Swiss forms (marked " S " in the list) and one Würtemburg species (marked " W "), the remaining 61 forms being new species and varieties at the time of their determination :

	Name.	*Horizon of representative European coral.*
	Actinozoa—	
	Lophosmilia tenuicaulata Greg.,	Cenomanian.
	,, *magnocaulata* Greg.,	,,
	Coelosmilia indica Greg.,	Senonian.
	Goniocora turbinata Greg.,	Corallian.
	Stylosmilia trapeziformis Greg.,	Portlandian.
	Stylina kachensis Greg.,	Bathonian-Callovian.
S.	*Astrocoenia bernensis* Koby.,	Corallian-Portlandian
	Stephanocoenia magna Greg.,	,,
	Favia baryphyllioides Greg.,	Kimmeridgian.
W.	*Placosmilia sessilis* Mil.,	Kimmeridgian.
	,, *kachensis* Greg.,	Portlandian.
	,, *scalpriformis* Greg.,	,,
	,, *caeliformis* Greg.,	Corallian.
	Trochosmilia indica Greg.,	,,
	Montlivaltia paleta Greg.,	Bathonian.
	,, *cornutiformis* Greg.,	,,
	,, *typica* Greg.,	Bajocian.
	,, *crassa* Greg.,	Bathonian
	,, *spissiradiata* Greg.,	Corallian.
	,, *obliquata* Greg.,	,,
	,, *cordata* Greg.,	,,

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[1] Perhaps identical with *R. concinna*, var. *kutchensis* Kitchin, which is found in the upper Pachham beds.

[2] *Pal. Ind.*, Ser. IX, Vol. II, Pt. 2 (1900).

	Name.	*Horizon of representative European coral.*
	Actinozoa—*contd.*	
	Montlivaltia elliptica Greg.,	Corallian-Kimmeridgian.
	,, *vasiformis* Greg.,	Kimmeridgian.
	,, *frustriformis* Greg.,	,,
	,, *kachensis* Greg.,	Bajocian.
	,, *culullus* Greg.,	Bathonian.
	Complexastraea kachensis Greg.,	Bajocian-Bathonian.
S.	*Isastraea propinqua* Th. & Et.,	Corallian.
	,, ,, var. *kachensis* Greg.,	,,
	,, *hemisphaerica* Greg.,	,,
	,, *exserta* Greg.,	Kimmeridgian.
	,, *parva* Greg.,	Bathonian.
	Thamnastraea crateriformis Greg.,	,,
S.	,, *mayeri* Koby.,	Corallian.
	,, ,, var. *indica* Greg.,	,,
S.	,, *valfinensis* Koby.,	Kimmeridgian.
	Dimorphastraea sigillum Greg.,	Neocomian.
	Centrastraea kobyi Greg.,	Bathonian.
	Stibastraea structa Greg.,	Corallian.
	,, *paeninsula* Greg.,	,,
	Latomaeandra humilis Greg.,	,,
	Archaeoseris thamnastraeoides Greg.,	? Neocomian.
	Comoseris jumarense Greg.,	Callovian.
	,, ,, var. *radiata* Greg.,	,,
	,, ,, var. *irregularis* Greg.,	,,
	,, *discontinua* Greg.,	Kimmeridgian.
	,, *plana* Greg.,	Bathonian.
	,, *microphyllioides* Greg.,	Callovian.
	Protethmos oldhami Greg.,	Neocomian.
	,, *duncani* Greg.,	,,
	Metethmos blanfordi Greg.,	Corallian.
	,, *griesbachi* Greg.,	,,
	Frechia cornutiformis Greg.,	Neocomian.
	Sematethmos sinuosa Greg.,	,,
	Kobya crassolamellosa Greg.,	Bajocian.
	,, *cancellata* Greg.,	,,
	,, *lenticulata* Greg.,	Callovian.
	Anabacia acaulis Greg.,	Bathonian.
	,, *fungiformis* Greg.,	,,
	Genabacia kachensis Greg.,	,,
	Trocharaea patelliformis Greg.,	Kimmeridgian.
	Trochoplegma tenuilamellosa Greg.,	Corallian.
	Microsolena subturbinata Greg.,	Bathonian.
	,, *variolata* Greg.,	,,
	Tricycloseris triangularis Greg.,	Kimmeridgian.
	,, *patelliformis* Greg.,	,,
	Dimorpharaea stellans Greg.,	Neocomian.
	,, *distincta* Greg.,	Kimmeridgian.
	,, *continua* Greg.,	,,
	,, *orbica* Greg.,	? Bathonian.
	Thamnaraea amorpha Greg.,	? Kimmeridgian-Neocomian.
	,, *tuberosa* Greg.,	Trias.

The horizon indicated, though not very definite, is Upper Bathonian or Callovian.[1]

The most striking features of the Jumara coral bank are the prevalence of small patelliform corals and of rounded nodular coralla in the massive forms, and a marked absence of arborescent growths so common in the European Jurassic species. Among the European Bathonian and Callovian faunas the Cutch corals most closely resemble those of the Crimea and Galicea. Of the brachiopods determined by Dr. Kitchin, the genera, *Kutchithyris*, *Flabellothyris*, *Cryptorhynchia* and *Kutchirhynchia* occur at various horizons in the Bathonian of Europe; the Pachham species are:

Brachiopoda—
Terebratula (*Kutchithyris*) *acutiplicata* (Kitch.),
,, *propinqua* Kitch.,
,, *katametopa* Kitch.,
,, *jumarensis* Kitch.,
,, *planiconvexa* Kitch.,
Flabellothyris dichotoma Kitch.,
Rhynchonella pseudo-inconstans Kitch. (cf. *R.* (*Burmirhynchia*) *injusta* Buckm. from the Namyaus of Burma),
,, (*Kutchirhynchia*) *kutchensis* (Kitch.),
,, (*Cryptorhynchia*) *pulcherrima* Kitch. (cf. *C. avonensis* Buckm. of England),
,, ,, *rugosa* Kitch. (cf. *C. bradfordensis* Marsh. and *C. vaughan* Marsh. from England).

Four species of *Trigonia* from the same beds, *T. tumida*, *T. prora*, *T. hispida and T. jumarensis*, have been identified, all new at the time of their determination. In addition to these the following lamellibranchs from various horizons in the Pachham series have been recognised by Dr. L. R. Cox[2]; the examination of the Jurassic lamellibranchs of Cutch has not yet been completed :

Lamellibranchiata—
Palaeoneilo belaënsis Cox (from the "*Corbula*" beds),
Bakevellia waltoni Lycett (from the "*Corbula*" beds ; a European form),
Isognomon (*Mytiloperna*) *patchamensis* Cox (from the "*Corbula*" beds),
Modiola patchamensis Cox,
,, *imbricata* Sow. (from the "*Corbula*" beds and other horizons ; found also in Europe and British Somaliland),
Grammatodon andhouensis Cox (from the Pachham dolomite),
Echinotis echinata Smith (from the Pachham dolomite ; found also in Europe, Tanganyika and New Zealand),

In the Pachham series two zones of cephalopods are recorded, the lower with some badly preserved macrocephalitids, *Sivajiceras congener* (Waagen), and *Epimorphoceras decorum* (Waagen), and the upper, occurring in the white limestones and intervening shales and containing :

CEPHALOPODA—
  Nautiloidea—
    Paracenoceres jumarense (Waag.),
    ,, *calloviense* (Opp.) (M.)
  Oppelidae.—
    Oppelia sp. (*aspidoides* group),
    Paroecotraustes (*Oecotraustes* ?) sp.

  Macrocephalitidae.—
    Macrocephalites triangularis Spath.,
    ,, *madagascariense* Lem. (B. M.).,
    ,, (*Kamptokephalites*) *dimerus* Waag. (doubtful).

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[1] J. W. Gregory. *Pal. Ind.*, Ser. IX, Vol. II, Pt. 2, 4 (1900).

[2] *Pal. Ind.*, Ser. IX, Vol. III, Pt. 3 (1940).

Cephalopoda—*contd.*

Phylloceratidae.—
Ptychophylloceras vicarium (Waag). (M.),
Phylloceras aff. *hatzegi* Loczy (aff. E.) M. Found in Madagascar.
Perisphinctidae.— B. ,, ,, Baluchistan.
Sivajiceras aff. *congener* (Waag.)
Procerites hans (Waag.). E. ,, ,, Alpine mediterranean area.

In these uppermost white limestones the dominant forms are very large *Macrocephalites*, often with the body chamber complete. The Macrocephalitidae play an important role in the Upper Pachham beds, as we shall see they also do in the Lower Chari. Waagen's original opinion that the Pachham series corresponds to the European Bathonian has been very generally accepted by later observers.

The Chari Series.—The next series in ascending order derives its name from the village of Chari, a famous fossil locality situated close to the borders of the Rann, about 32 miles northwest of Bhuj ; cephalopods especially are abundant and large numbers are found in the calcareous sandstones exposed around Kira hill. This series, although exposed in several places, nowhere occupies a large area. It is composed of four subdivisions, each marked by its mineral characters and its fossils. As a whole the group is much more shaly than any of the others, but hard bands of limestone or calcareous sandstone are included and form ridges which are usually distinguished by characteristic ammonites.

The Chari beds rest upon the Pachhams in the southern parts of Pachham and Khadir and in two small islands southeast of Khadir ; in one of the latter they form part of a dome. In these outcrops the subdivisions are less well marked than to the southward, and the two characteristic Terebratulae, *T.* aff. *biplicata* (Sow.) and *T.* (*Lophrothyris*) *euryptycha* Kitch [1], have not been noticed. None of the Chari beds is observable in Bela or Chorar, but a small exposure exists in the extreme north of Wagur. In the mainland of Cutch the Chari series occupies two rows of inliers. One of these rows coincides with the median anticlinal range along which outcrops are scattered at intervals. The other row occurs in the Charwar range, south of Bhuj, where the Chari beds are brought up at intervals along the southern side of the great fault ; here they are greatly disturbed and cut up by cross faults, but the different bands can be easily recognised, the Dhosa oolite with *Terebratula* (*Lophrothyris*) *euryptycha* Kitch. the white *Peltoceras* ("*Athleta*") beds, and the band with the so-called *Terebratula* aff. *biplicata*, being always conspicuous. The fossils of the Chari group include eight echinoids, of which two are European forms, *viz. Holectypus sarthacensis* Cott. and *Collyrites dorsalis* Ag. & Des., and a third is closely allied to *Collyrites bicordata* (Leske), a form found in Europe, Algeria and elsewhere. The others have been named by Gregory, *Rhabdocidaris* sp., *Pseudocidaris unigranulatus* (possibly from the Upper Pachham and not the Chari), *Pseudodiadema kachensis*, *Somechinus* sp. and *Pygorhytes tumulus*. One of the eight corals is a variety (*indica*) of the European *Astrocoenia bernensis* Koby, another is a variety (*kachensis*) of the European *Thamnastraea valfinensis* Koby, while the rest are new species : *Amphiastraea piriformis* Greg., *Montivaltia chariensis* Greg., *Isastrocoenia kachensis* Greg. (horizon doubtful), and the three Pachham species *Comoseris irregularis* Greg., *Kobya crassolamellosa* Greg., and *K. cancellata* Greg[2]. Of the brachiopods, most of them belonging to the two genera, *Terebratula* and *Rhynchonella*, two come from unknown horizons, *R. recticardinalis* Kitch. and an indeterminable species comparable thereto. The Golden Oolite has yielded :

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[1] Formerly thought to be a variety of *T. sella*

[2] *Pal. Ind.*, Ser. IX, Vol. II, Pt. 2, pp. 31-33 (1900).

Brachiopoda—

Terebratula aurata Kitch. (showing resemblances to certain Inferior Oolite forms, and to *T. fleischeri* from the Dogger),
,, *longiplicata* Opp. (a European form),
,, *breviplicata* Kitch.,
Rhynchonella (*Kutchirhynchia*) *kutchensis* (Kitch.),
,, (*Kallirhynchia*) *indica* d'Orb. (horizon doubtful ; cf. *K. anglica* Buckm. and *K. constricta* Buckm. from the Namyaus of Burma).

From higher horizons come :

Terebratula breviplicata Kitch. (from beds overlying the Golden Oolite),
,, (*Lophrothyris*) *curyptycha* Kitch. (ranging from just above the Macrocephalus Beds to the top of the Chari group ; cf. *T.* (*L.*) *etheridgei* from England),
,, *hypsogonia* Kitch., (below the Anceps zone),
,, *longicarinata* Kitch., (just above beds with *T. hypsogonia*),
,, *dhosaensis* Kitch. (beneath the Anceps zone),
,, *ingluviosa* Kitch. (Dhosa Oolite),
,, *pyroidea* Kitch. (Dhosa Oolite),
,, *jooraensis* Kitch. (Dhosa Oolite),
Dictyothyris compressa Kitch. (exact horizon unknown),
Zeilleria rostellata Kitch. (uncommon ; Dhosa Oolite),
Tersbratulina inflata Kitch. (exact horizon unknown),
Rhynchonella nobilis Sow. (about the middle of the series and perhaps higher ; cf. *R. decorata* Schloth. from Europe),
,, *microrhyncha* Sow. (exact horizon unknown),
,, *brevicostata* Kitch. (from beds containing *R. microrhyncha* & *R. nobilis*),
,, (*Kallirhynchia*) *fornix* Kitch. (Dhosa Oolite and below ; cf. *R. concinna*),
,, (? *Kallirhynchia*) *subplicatella* Kitch. (either Dhosa Oolite or just below),
,, (*Kallirhynchia*) *versabilis* Kitch. (below Dhosa Oolite and perhaps from that zone also ; cf. *K. crassicosta* Buckm. and *K. yaxleyensis*,
,, (*Sphenorhynchia*) *asymmetrica* Kitch. (exact horizon unknown ; cf. *Rhactorhynchia argillacea* Buckm.,
,, *pauciplicata* Kitch. (exact horizon unknown),
,, *major* Sow. (horizon doubtful).

None of these species is described as identical with any known form. The species of *Trigonia* listed below are described as all new[1] :

Lamellibranchiata—

Trigonia tumida Kitch.,
,, *chariensis* Kitch.,
,, *propinqua* Kitch.,
,, *brevicostata* Kitch.,
,, *distincta* Kitch.,
,, *acuta* Kitch.,
Trigonia dhosaënsis Kitch.,
,, *nitida* Kitch.,
,, *kutchensis* Kitch.,
,, *exortiva* Kitch.,
,, *gracilis* Kitch.

In addition, the following lamellibranchs from the Lower Chari *Macrocephalus* beds have been determined by Dr. L. R. Cox[2] :

Nucula (*Palaeonucula*) *cuneiformis* Sow.,
,, ,, *kaoraënsis* Cox., (Sowerby's *N. tenuistriata*),
,, ,, *blanfordi* Cox.,
,, ,, *stoliczkai* Cox.,
Nuculoma wynnei L. R. Cox (probably identical with Douvillé's *Nucula tenuistriata* Sow. from Sinai),
,, *blakei* Cox.,
Nucula (*Dacryoma*) *lacryma* (Sow.) (form found in the Great Oolite of England),
Grammatodon (*Indogrammatodon*) *virgatus* (Sow).

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[1] F. L. Kitchin. *Pal. Ind.*, Ser. IX, Vol. III, Pt. II, pp. 120 (1903).

[2] *Pal. Ind.*, Ser. IX, Vol. III, Pt. III, 1940.

Modiola imbricata Sow.,
,, *glendayi* (Weir) (British Somaliland form),
,, cf. *bipartita* Sow. (European form),
,, (*Inoperna*) *plicata* Sow., (found also in Europe, East Africa, Kashmir, Persia and Bahrein Island),
Lithophaga sp.,
Brachydontes (*Arcomytilus*) *laitmairensis* (do Loriol) (found also in Europe and British Somaliland),
Echinotis echinata (Smith),
Posidonomya ornati Quen. (found also in Europe and the Dutch East Indies),
Bakevellia waltoni (Lycett),
Isognomon (*Mytiloperna*) *patchamensis* Cox,
Eligmus rollandi Douv. (Europe, Somaliland, Southern Arabia and Madagascar).

The large number of cephalopods have been arranged into several zones described below. *Belemnites* are common, especially in the Dhosa Oolite, nearly all of them belonging to the deeply grooved *Belemnopsis* . Dr. Spath notes that in the upper two stages of the Chari, as well as in the Kantkot Sandstone which follows them, the Mayaitidae play as important a role as do the Quenstedtocerates and Cardiocerates of more northern latitudes. In the Chari and throughout the rest of the Cutch Jurassic succession the genus *Phylloceras* is not so dominant as it is in the Mediterranean area ; the Oppelidae on the other hand are abundant. From the Chari group has been collected a single amphicoelous vertebra which may be crocodilian. Above the Pachham coral bank Dr. Spath distinguishes three sub-stages characterised by *Macrocephalus*. Of these the Lower *Macrocephalus* beds have always been grouped with the Pachhams and spoken of as the Pachham limestone or white limestone ; it has already been described.

The Golden Oolite.—The Middle and Upper Macrocephalus beds constitute the lowest of the five stages of the Chari series, the Golden Oolite. This consists of shales, usually of a grey colour, with occasional bands of "golden oolite.", and sometimes nodular shaly limestone. The golden oolite, like that found at about the same horizon in the Jurassic of Europe, is very characteristic and easily recognised. It is a rather coarse-grained limestone, composed of calcareous grains coated with a very thin ferruginous layer and surrounded by a matrix of carbonate of lime. In places, as at Chari itself, the Golden Oolite is thick and conspicuous, but is locally distributed and often wanting.

At Jumara the lowest of the Chari stages has a facies quite different from that of the Golden Oolite and consists of shales with red ironstone bands and nodules, the Middle *Macrocephalus* beds, and of overlying limestones known as the Upper *Macrocephalus* beds. These have been grouped into five zones according to their typical ammonites :

	Typical ammonites.
Upper Macrocephalus beds	(*e*) *Dolikephalites subcompressus* (Waag.), *Macrocephalites chariensis* spp., *Kamptokephalites magnumbilicatus* (Waag.).
Middle Macrocephalus beds	(*d*) *Dolikephalites subcompressus* (Waag.), *Nothocephalites semilaevis* (Waag.), *Kamptokephalites* aff. *magnumbilicatus* (Waag.).
	(*c*) *Macrocephalites chariensis* (Waag.), *Kamptokephalites dimerus* (Waag.), *Indosphinctes* spp.
	(*b*) *Macrocephalites chariensis* (Waag.), *Alcidia* spp., *Paroecotraustes* sp., *Parapatoceras* sp.
	(*a*) *Macrocephalites chariensis* (Waag.), *Kamptokephalites dimerus* (Waag.), *Pleurocephalites habyensis* Spath, *Indocephalites* spp.

Most of the Middle Macrocephalus types, zones (*a*) to (*d*), are similar to those occurring in the English Cornbrash, though none of the species is common to both. They include :

CEPHALOPODA—

Belemnoidea—
Belemnopsis subhastata (Ziet.) Waag.

Nautiloidea—
Procymatoceras ? intumescens (Waag.) (B.),
Paracenoceras cf. *calloviense* (Opp.).

Phylloceratidae—
Calliphylloceras aff. *demidoffi* (Rouss.).

Oppelidae—
Alcidia sp.,
Hecticoceras turgidum Loczy (cf. E.').

Macrocephalitidae—
Macrocephalites formosus (Sow.) (B. M.),
,, *chariensis* (Waag.), (K. M.) ; and a variety, *Seminuda* Spath,
Indocephalites transitorius Spath,
,, *diadematus*(Waag.),
,, *kheraensis* Spath, (M),
,, *indicus* Spath,
,, *chrysoolithicus* (Waag.) (aff. M.),
,, *sphaeroidalis* Spath,
,, *gibbosus* Spath (aff. B.),
Pleurocephalites habyensis Spath (M. group B.),
,, *elephantinus* (Sow.) (M., equivalent of *P. besairei* and *Kamptokephalites misorobensis*),
Kamptokephalites dimerus (Waag.) (aff. M.),
,, *lamellosus* (Sow.) (M. variety, *subtrapezinus*),
,, ,, var. *aureus* Spath,
Kheraiceras cosmopolita (Par. & Bon.).

Reineckeiinae—
Parapatoceras cf. *calloviense* (Morr.) (cf. E.).

Perisphinctidae—
Choffatia aff. *furcula* (Neum.). (aff. E.),
,, aff. *recuperoi* (Gemm.) (species K. and M. ; aff. B.) (aff. E.).

B, found in Baluchistan. K. found in Kenya. E, found in the Alps & the Mediterranean area.
M, ,, ,, Madagascar. E,' ,, ,, Middle & Western Europe.

Inspite of the persistence of *Macrocephalites* and *Kamptokephalites*, zone (*e*) is typically Lower Callovian in its affinities; its index fossil might well be *Macrocephalites chariensis* (Waag.). The increase in the number of oppelids and perisphinctids is as striking as the decrease of macrocephalitids. This fauna consists of :

Cephalopoda—

Belemnoidea—
Belemnopsis cf. *grantiana* (d'Orb.) ?
,, *subhastata* (Ziet.),
Hibolites jumarensis (Waag.).

Nautiloidea—
Paracenoceras cf. *calloviense* (Opp.).

Phylloceratidae—
Calliphylloceras aff. *demidoffi* (Rouss.).

Lytoceratidae—
Thysanolytoceras adeloides (Kud.).

Oppelidae—
Paroecotraustes aff. *serrigerus* (Waag.) (aff. E.'),
,, aff. ,, var. *densecostata* Liss. (aff. E'.),
,, cf. *subfuscus* (Waag.) (cf. E.'),
Alcidia dubia Spath (M. equivalent to *A. subcostata*),
,, aff. *obsoleta* (Roll.) (Species M. aff. E.'),
,, *inflata* Spath.,
,, *mimetica* Spath.,
,, *nurrhaënsis* (Waag.),
Chanasia fornix (Sow.) (Genus M.),
Hecticoceras giganteum Spath.,
,, aff. *turgidum* Loczy (cf. E.'),
Kheraites smithi path.,
,, *ignobilis* (Sow.).

Macrocephalitidae—
Macrocephalites formosus (Sow.) (B. M.),
,, *chariensis* (Waag.) (K. M.),
,, ,, , var. *seminuda* Spath.,
Kamptokephalites magnumbilicus (Waag.) (aff. K.),
,, *lamellosus* (Sow.),
Dolikephalites subcompressus (Waag.).

Eucycloceratidae—
Nothocephalites semilaevis (Waag.) (aff. K.),
,, *asaphus* Spath.

Perisphinctidae—
Indosphinctes errans Spath. (aff. B.),
,, *peregrinus* Spath.,
,, *natwaris* Spath.,
,, *patina* (Neum.) (M. E.),
,, *patiniformis* Spath (M),
,, *urbanus* Spath (M.),
,, aff. *abichi* (Neum. & Uhl.) (aff. E.),
,, *rusticus* Spath,
Choffatia perdagata (Waag.),
,, *sakuntala* Spath.,
,, *madani* Spath.,
,, aff. *furcula* (Neum.),
,, aff. *ybbsensis* (Yüss.) (aff. E.).
,, aff. *recuperoi* (Gemm.) (species K. & M. ; aff. B. & E.),
,, *baluchistanensis* (Noetl.),

Cutchisphinctes altiplicatus (Waag.) (Genus found in Roumania).

B, found in Baluchistan.
M, ,, ,, Madagascar.
K, ,, ,, Kenya Colony.
E, ,, ,, Alps & Mediterranean area.
E,' ,, ,, Middle & Western Europe.

Rehmanni Stage.—Between the Upper Macrocephalus limestones and the Anceps beds there occurs in the Jumara area a yellow limestone stage, the Rehmanni beds, in which the following two zones of ammonites have been identified :

(i) *Reineckeia tyranniformis* Spath, *Sivajiceras kleidos* Spath, *Idiocycloceras singulare* Spath.

(ii) *Reineckeia rehmanni* (Oppel), *Kellawaysites greppini* (Oppel), *Sivajiceras* cf. *fissum* (Sow.) *Idiocycloceras singulare* Spath.

These zones are also assigned to the Lower Callovian. The Rehmanni fauna from these two zones consists of:

CEPHALOPODA—
Belemnoidea—
Belemnopsis calloviensis (Opp.) (P. E.').

Nautiloidea—
Paracenoceras kumagunense (Waag.) (M.),
,, *calloviense* (Opp.) (M. cf. E.').

Phylloceratidae—
Calliphylloceras aff. *disputabile* (Zitt.) (Species M. aff. E.),
,, aff. *demidoffi* (Rouss.),
,, *lodaense* (Waag.),
Holcophylloceras mediterraneum (Neum.) (M. E.),
,, *mesolcum* (Dietr.) (=aff. *polyolcum* (Benecke)).

Lytoceratidae—
Thysanolytoceras adeloides (Kud.) (M.E.).

Oppelidae—
Hecticoceratoides suborientalis Spath. (M.),
Kheraites crassefalcatus (Waag.),
Lunuloceras orientale (d'Orb.).

Macrocephalitidae—
Macrocephalites cf. *chariensis* ? (Waag.) (K. M.),
Dolikephalites subcompressus (Waag.),
Kamptokephalites magnumbilicus (Waag.).

Eucycloceratidae—
Eucycloceras eucyclum (Waag.),
,, *pilgrimi* Spath,
Subkossmatia opis (Sow.),
,, *obscura* Spath.,
,, *coggin-browni* Spath,
,, *ramosa* Spath,
Idiocycloceras perisphinctoides Spath,
,, *singulare* Spath,
Notocephalites semilaevis (Waag.).

Reineckeidae—
Reineckeia tyranniformis Spath, *R. substeinmanni* (locality doubtful). (E'.),
,, aff. *rehmanni* (Opp.) (aff. E.'),
,, *? indosabauda* (Par. & Bon.),
Kellawaysites greppini (Opp.) *oxyptychus* (Neum.) (P).

Perisphinctidae—
Sivajiceras paramorphum (Waag.),
,, *kleidos* Spath,
,, *aureum* Spath,
,, *robustum* Spath,
,, aff. *fissum* (Sow.),
Hubertoceras arcicosta (Waag.) (M.),
Indosphinctes calvus (Sow.),
,, *indicus* (Siem.),
,, *errans* Spath, (aff. B.),
,, *peregrinus* Spath,
Choffatia leptonota Spath,
,, *perdagata* (Waag.),
,, *balinensis* (Neum.) (B. P. E.),
,, *lateralis* (Waag.),
,, *baluchistanensis* (Noetl.) (B.),
,, *transitoria* Spath,
,, *mediocris* Spath,
,, aff. *recuperoi* (Gemm.) (Species K. and M.; aff. B. and E.),
,, *soorkaensis* Spath,
,, *gottschei* (Steinm.),

Kinkeliniceras angygaster (Waag.) (Genus in Tanganyka).
B, found in Baluchistan. K, found in Kenya.
M, ,, ,, Madagascar. E, ,, ,, Alps & Mediteranean area.
P, ,, ,, Persia. E', ,, ,, Middle & Western Europe.

In addition to the cephalopoda there are various echinoderms and brachiopods and a fine series of mollusca which have not yet been described; amongst them Dr. Spath notes *Astarte pisiformis* Sow., *Nucula* spp., *Lima* (*Radula*) *cardiiformis* Morr. & Lyc. and other species, *Ostraea*, *Arctostraca*, *Hinnites*, *Rhynchonella*, *Terebratula*, *Procerithium*, etc. The "Rehmanni" stage is probably present at Khera, Walakhavas and Ler Hamundra also.

"Anceps" Stage.—The next higher stage,—in many places, apparently immediately succeeding the Macrocephalus beds,—comprises dark shales, often black, with ferruginous bands and concretions. Sometimes, however, the nodules are of white limestone, and the shales are locally sandy and associated with sandstones. The chief palæontological peculiarity of these Anceps beds, as they are called, is the extreme abundance of a *Terebratula* regarded by Sowerby as a variety of the Cretaceous *T. biplicata*.[1] The shales not infrequently contain plant remains, but no determinable impressions are recorded. Chiefly on the evidence of the Jumara section the Anceps Beds have been divided into two zones :

Upper "Anceps" Beds (yellow limestone).	*Kinkeliniceras* sp., *Hubertoceras mutans* (Waag.) *Reineckeites* spp.
Lower "Anceps" Beds (sandy, calcareous shales).	*Reineckeia ? ravana* Spath, *Indosphinctes calvus* (Sow.), *Sivajiceras fissum* (Sow.).

The lower zone includes *Reineckeia smithi* Spath, *R. reissi* Steinm. and other species formerly included under the term *Perisphinctes anceps*. A better name for this series would be the "Reineckeia" series, in which, however, the preceding "Rehmanni" beds would have to be included. The fauna of the Lower "Anceps" (Middle "Reineckeia") beds comprises :

CEPHALOPODA—
Belemnoidea—
Belemnopsis calloviensis (Opp.) (P E'.),
,, *subhastata* (Ziet.) (E') (1) Either lower or Upper Anceps Beds.

Nautiloidea—
Paracenoceras kumagunense (Waag.) (M.),
Pseudaganides kutchensis (Waag.).

Phylloceratidae—
Phylloceras cf. *subobtusum* (Kud.) (cf. E.),
Calliphylloceras aff. *demidoffi* (Rouss.) (aff. E.),
Holcophylloceras mediterraneum (Neum.) (E.).

Lytoceratidae—
Thysanolytoceras adeloides (Kud.) (M. E.).

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[1] With this type Kitchin equates his *Terebratula aurata*, but the 30 well preserved specimens on which the latter was founded are described as having been collected from the "Golden Oolite" of Kira Hill (*Pal. Ind.*, Ser. IX, Vol. III, Pt. 1,19 (1900)).

Oppelidae.—
Sindeites waageni Spath (Genus known only in Cutch, Rajputana, Madagascar and Kenya Colony),
Kheraites (?) *varicosus* Spath,
,, *ferrugineus* Spath,
Lunuloceras orientale (d'Orb.),
Sublunuloceras prelairense Spath.

Incertae sedis.—
Oecoptychius refractus (Rein.) (E'. and elsewhere),

Eucycloceratidae.—
Subkossmatia discoidea Spath,
Idiocycloceras dubium Spath.
Reineckeidae.—
Reineckeia arthritica (Sow.),
,, aff. *brancoi* (Steinm.) (Species P.),
,, *indosabauda* (Par. & Bon.),
,, *smithi* Spath,
,, *ravana* Spath,
,, *reissi* Steinm. (M. aff. Rajputana),
,, *lifolensis* Steinm,
Kellawaysites oxyptychoides Spath (cf. *K. greppini*, E.).
Perisphinctidae.—
Sivajiceras aureum Spath,
,, *fissum* (Sow.),
,, *subfissum* Spath,
Obtusicostites obtusicosta (Waag.),
,, *waageni* Spath,
,, *buckmani* Spath,
Kinkeliniceras angygaster (Waag.), (Tanganyika),
,, *kinkelini* (Dacq.) (K.),
,, *subwaageni* Spath,
,, *discoideum* Spath,
Hubertoceras arcicosta (Waag.),
,, *mutans* (Waag.),
,, ,, var. *evoluta* Spath,
,, *dhosaense* Spath,

Choffatia cobra (Waag.),
,, *balinensis* (Neum.) (B. P. E.),
,, *naia* Spath,
,, *lateralis* (Waag.),
,, *baluchistanensis* (Noetl.) (B.),
,, *transitoria* Spath,
mediocris Spath,
,, *simulans* Spath,
,, (? *Grossouvria*) *aurita* Spath,
Grossouvria calloviensis (Loczy) (E. aff. K.),
,, aff. *leptoides* (Till) (aff. E.),
,, *anomala* (Loczy) (E.),
,, *curvicosta* (Opp.) (P. E'.),
,, *evexa* (Quenst.) (E'. cf. *G. subtilis*, P.),

Subgrossouvria aberrans (Waag.),
,, *gudjinsirensis* (Wagg.),
,, ,, , var. *tenuis* Spath,
,, cf. *coronaeformis* (Loczy) (cf. E.).

From the Upper "Anceps" (Upper "Reineckeia") Beds Come:

Belemnoidea.—
Belemnopsis calloviensis (Opp.) (P. E'.).

Nautiloidea.—
Paracenoceras kumagunense (Waag.) (M.).

Phylloceratidae.—
Ptychophylloceras sp.,
Calliphylloceras aff. *demidoffi* (Rouss.) (aff. E.).

Lytoceratidae.—
Thysanolytoceras adeloides (Kud.) (M. E.).

Oppelidae.—
Phlycticeras waageni Buckm.,
,, *schaumburgi* (Waag.) (cf. M.),
Subbonarellia decipiens Spath,
Putealiceras sp. (trans. to *Kheraites*),
Sublunuloceras lairense (Waag.).

Reineckeidae.—
Reineckeia aff. *reissi* Steinm. (Species M.; aff. Rajputana),
,, aff. *lifolensis* (Steinm.) Couffon,
Kellawaysites spp.,
Reineckeites waageni (Till),
,, ,, , var. *regalis* Spath,
,, *torulosus* Spath,
,, cf. *hungaricus* (Till) (cf. E.),
,, *crispus* Spath,
,, *jumarensis* Spath,
Collotia kachhensis Spath,
,, (*Reineckeia ?*) *octagona* Spath.

Perisphinctidae.—
Obtusicostites obtusicosta (Waag.),
,, *purpuratus* Spath,
,, ,, , var. *rotunda* Spath,
Kinkeliniceras kinkelini (Dacq.) (K.),
,, ,, , var. *senilis* Spath,
,, *discoideum* Spath,
,, *indra* Spath,
,, *varuna* Spath,
,, *crassiplanula* Spath,
,, *krishna* Spath,
,, *pseudomaya* Spath,
Hubertoceras hubertus Spath,
,, ,, , var. *flexicostata* Spath,
Grossouvria curvicosta (Oppel.),
Subgrossouvria blakei Spath,
,, *morley-daviesi* Spath,
,, *stenoniformis* Spath,
Orionoides pseudorion (Waag.),
,, *purpurus* Spath.

Aspidoceratidae.—
Peltoceras sp. (*kachhense* group) (aff. E'.),
Pseudopeltoceras retrorsum Spath.

Among the brachiopods and lamellibranchs found in the Upper Anceps Beds are[1]

Lopha cf. *hastellata* (Quenst.) de Lor.,
Exogyra '*conica*' Sow.,
Ostrea '*carinata*' Sow.,
Plicatula pectinoides Sow.,
Lima impressa Morr. & Lyc.,
L. aff. *duplicata* Sow.,
Pecten partitus Sow.,
Hinnites cf. *bonjouri* de. Lor.,
Ctenostreon proboscideum Phill. Douv.,
C. cf. *squammicosta* (Brug.) de Lor.,
Cueullaea virgata Sow.,
Trigonia brevicostata Kitch.,
Astrarte cf. *rotunda* Sow.,
Protocardia aff. *concinna* (Buckm.),
Ceromya concentrica (Sow.),
C. cf. *inflata* (Voltz) Agasc.,
Pholadomya angulata Sow.,
P. granosa Sow.,
P. inornata Sow.,
Pleuromya ovale (Sow.),
P. hianns (Sow.),
Rhynchonella microrhyncha Sow.,
R. pseudoinconstans Kitch.,

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[1] *Pal. Ind.* New Ser. IX, Mem. 2, 774 (1929).

Trigonia propinqua Kitch.,
T. chariensis Kitch.
R. subplicatella Kitch.,
Alectryonia sp., and *Nucula* sp.

The age of the Anceps stage is Middle Callovian.

"Athleta" Stage.—The next stage of the Chari series, in ascending order, is a very thin band, sometimes only 20 or 30 feet thick, of light grey shale, with layers of limestone, which are generally white but occasionally yellowish or brown in colour. Usually this Athleta stage is recognisable by its colour and its position beneath the Dhosa Oolite. In the Jumara section it is represented by yellow marls overlying gypsiferous shales, and has been divided into three zones :—

(3) *Metapeltoceras* spp., *Peltoceras ponderosum* Waag. et spp., *Orionoides indicus* Spath.

(2) *Peltoceras metamorphicum* Spath, *Orionoides purpurus* Spath.

(1) *Peltoceras* spp. including *P. kachhense* Spath., *Reineckeites* sp.

These zones include more than one species of *Peltoceras*, especially *P. kachhense* of the lower zone, originally "*Ammonites* (*Peltoceras*) *athleta*", after which the stage has been called. The age of the lowest zone is Lower Divesian, that of zones (2) and (3) Upper Divesian.

The cephalopod fauna of the Athleta Beds is as follows :

CEYHALOPODA—
  Belemnoidea.—
    Belemnopsis calloviensis (Opp.) (P. E'.),
    Hibolites cf. *hastatus* (Blainv.) (Species E'.),
  Nautiloidea.—
    Paracenoceras kumagunense (Waag.) (M.),
  Phylloceratidae.—
    Phylloceras cf. *plicatum* Spath,
    Calliphylloceras aff. *demidoffi* (Rouss.) (aff. E.);
  Lytoceratidea.—
    Thysanolytoceras adeloides (Kud.) (M. E.),
  Oppelidae.—
    Bonarellia nodulosa (Quenst.) (E'.),
    Sindeites aff. *waageni* Spath,
    Subbonarellia manialensis Spath,
    Putealiceras trilineatum (Waag.),
        ,,   ,,   var. *crassa* Spath,
        ,,   ,,   var. *compressa* Spath,
        ,,   *vijaya* Spath,
        ,,   *intermedium* Spath,
        ,,   ,,   , var. *robustum* Spath,
        ,,   ,,   , var. *samatrensis* Spath
        ,,   *pseudodynastes* Spath,
        ,,   *bisulcatum* Spath,
    Lunuloceras ? *nisoides* Spath (E'.),
    Brightia sp.
      (Genus P. E'.),

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[1] The following Middle Chari forms have been determined by Dr. L. R. Cox (*Pal. Ind.* Ser. IX, Vol. III, Pt. 3 (1940) :

From the Anceps beds : *Grammatodon* (*Indogrammatodon*) *virgatus* (Sow.) (perpaps also in the Rehmanni zone) ; perhaps *Gr.* (*Ind.*) *blakei* Cox ; *Lithophaga* sp., and *Trichites indicus* Cox.

From the Rehmanni or Anceps beds : *Modiola glendayi* (Weir).

Sublunuloceras lairense (Waag.),
,, aff *nodosulcatum* (Lah.) (aff. E.').
,, *dynastes* (Waag.),
,, *discoides* Spath,
Aptychus (*Cornaptychus*) aff. *hectici* (Quenst) (aff. E.) ;

Eucyloceratidae.—

Erymnoceras dorothae Spath,
Pachyceras indicum Spath (S.),
,, *distinctum* Spath ;

Reineckeidae.—

Collotia aff. *angustilobata* (Bras) (aff. E'.),
,, *draupadi* Spath,
,, aff. *fraasi* (Opp.) (aff. E^1.);

Perisphinctidae.—

Obtusicostites devi Spath,
,, ,, var. *crassa* Spath,
,, *ushas* Spath,
,, *nandi* Spath,
Kinkelinoceras catillus Spath,
Hubertoceras hubertus Spath,
,, ,, , var. *densicostata* Spath,
,, ,, , var. *rotunda* Spath,
,, *omphaloides* (Waag.) (cf. M. ; ? S.),
,, ,, , var. *polymorpha* Spath,
,, ,, , var. *herculea* Spath,
,, ,, , var. *depressa* Spath,
Grossouvria evexa (Quenst.) (E'. cf. *Gr. subtilis*, P.),
,, aff. *kontkiewiczi* (Siem.) (aff. E'.),
,, *nurrhaensis* Spath,
,, *ophioides* Spath,
Subgrossouvria intermedia Spath,
,, *morley-daviesi* Spath,
Poculisphinctes kachhensis Spath,
Orionoides samatrensis Spath,
,, *sita* Spath,
,, *indicus* Spath,
,, (?) *crioceras* Spath,
Binatisphinctes aff. *riasanensis* (Teiss) (Species P. ; aff E'. Genus M.),
,, cf. *subaurigerus* (Teiss.) (cf. E'.),
Prososphinctoides manialensis Spath,

Aspidoceratidae.—

Peltoceras kachhense Spath (aff. E'. Identical with some of the forms originally called *P. athleta*) (M.),
,, *metamorphicum* Spath (E'.),
,, *tetragonum* Spath,
,, *kumagunense* Spath,
,, *solidum* Spath (in part *P. athleta*),
Metapeltoceras armiger (Sow.) (Genus M.),
,, *diversiforme* (Waag.),
Euaspidoceras pyrrha Spath ;

Nautiloidea.—

Paracenoceras kumagunense (Waag.) (M),

Phylloceratidae.—

Phylloceras riazi (de Lor.) (E.),
,, *chantrei* (Mun -Ch) (E.),
Sowerbyceras transiens (Pomp.) (E.),
Ptychophylloceras feddeni (Waag.),

Oppelidae.—
Paralcidia khengari Spath,
Bonarellia bicostata (Stahl) (E'.),
Horioceras baugieri (d'Orb.) (E'.),
Putealiceras intermedium Spath,
,, *punctatum* (Stahl) (E'. ; cf. P.),
,, *bisulcatum* Spath,
Sublunuloceras ? cf. *inermis* (E Douv.) (cf. E'.),
Trimarginites (?) aff. *rollieri* (de Lor.) (aff. E.'),
Lorioloceras cf. *inconspicuum* (P. de Lor.) (cf. E'.),
,, *canaliculatum* (Quenst.) (E'.),
Perisphinctidae.—
Hubertoceras spp. (*omphalodes* group),
Grossouvria aff. *variabilis* (Lah.) (aff. E'.),
Orionoides (?) *anguinus* Spath,
Klematosphinctes mirandus (P. de Lor.) (E'.),
,, *perisphinctoides* (Sinz. de Lor) (E.'),
Properisphinctes bernensis (P. de Lor.) (E'.),
Prososphinctes cf. *consociatus* (Buk.) (E'.);
Aspidoceratidae.—
Peltoceras spp. (many fragments),
,, *ponderosum* (Waag.),
Metapeltoceras armiger (Sow.),
,, *diversiforme* (Waag.),
,, *flavum* Spath,
Euaspidoceras armatum (P. de Lor) (E'. ; *Eu. perarmatum*, M.),
,, *douvillei* (Coll.) (E'.),
,, *acanthodes* Spath,

Other fossils from the Athleta stage include the following :

Amphaeastraea sp.,
Pentacrinus sp.,
Pygaster sp.,
Rhynchonella nobilis Sow.,
Zeilleria sp.,
Arctostraea amor (d'Orb.) Douv.,
Lima gibbosa Sow.,
Pecten aff. *lens* Sow.,
Nucula (*Palaeonucula*) cf. *menkei* Roem., (Middle or upper part of the stage ; a European form),
,, ,, *cuneiformis* Sow.,
,, (*Rollieria*) cf. *meriani* (Rollier) (Middle of upper part of the stage)
,, (*Praesaccella*) *juriana* Cox,
Palaeoneilo indicus Cox, (Lower Athleta beds),
Pteroperna ? *blakei* Cox, (Lower Athleta beds),
Parallelodon lerensis Cox,
Grammatodon jurianus Cox, (close to the European *G. concinnus* (Phill.),
,, (*Indogrammatodon*) *virgatus* Sow.,
Modiola glendayi (Weir),
,, (*Inoperna*) *plicata* Sow.,
Bakewellia sp.,
Gervillia siliqua Desl. (found also in Europe, Suez and Tanganyika),
Inoceramus sp.,
Pinna stoliczkai Cox,
,, (*Stegoconcha*) cf. *G. mülleri* Krenk.,
Astarte unilateralis Sow.,
,, *compressa* J. de C. Sow.,
Pholadomya angulata Sow.,
Goniomya sp.,
Nerita sp.,
Alaria sp.,
Vertebrae and fish remains.

The Athleta fauna and the zone which immediately follows together represent the Upper Callovian. Of less certain horizon but belonging either to the Callovian or the Divesian are the following :

Nucula (*Palaeonucula*) *cuneiformis* Sow.,
Pinna cf. *mitis* Phil. (found also in Europe and East Africa),
,, (*Stegoconcha*) cf. *G. mülleri* Krenk., (found also in Tanganyika),
,, *stoliczkai* Cox,
Trichites indicus Cox.

Dhosa Oolite. The uppermost Chari stage, or Dhosa Oolite, is the most characteristic of all, both lithologically and palaeontologically. It is of no great thickness though more developed than the Athleta Beds, and consists of grey, reddish or brown oolite, sometimes sandy and often nodular. Cephalopods are abundant and in many places there are large numbers of a species of *Terebratula* named by Dr. Kitchin *euryptycha*[1], closely related to *T. elleridgei* of the English Inferior Oolite. At Jumara the following zones have been established :

Green Upper Dhosa Oolite.—
   3. *Taramelliceras jumarense* Spath, *Lithacoceras* aff. *kreutzi* Siem.
   2. *Mayaites maya* (Sow.), *Pcltoceratoides semirugosus* (Waag.).
Brown Lower Dhosa Oolite.—
   1. *Euaspidoceras* sp.

Zone 1 is equated with the Upper Divesian (*renggeri* zone), Zone 2 with the Lower Argovian (*cordatus* zone), and Zone 3 with the Upper Argovian (*transversarius* zone). The Dhosa Oolite, therefore, includes the topmost Divesian and most of the Argovian. It marks a break in the uniformity of the deposits ; in places it is a brown oolitic rock, often conglomeratic, with its fossils corroded and coated with oysters and showing a limonitic crust.[2] In the southern range the base of the Dhosa Oolite is formed by transitional shales succeeded by a hard sandy limestone, the equivalent of the Lower Dhosa Oolite in the north; its most characteristic feature is the presence of gigantic ammonites of the type of *Stephanoceras* (*Epimayaites*) *polyphemus* (Waag.).

The cephalopod fauna from the main bulk of the Dhosa Oolite, which we may designate the Lower Dhosa Oolite comprises :

CEPHALOPODA—

Belemnoidea.—
   Belemnopsis orientalis (Waag.),
   Hibolites sp. (*sauvanausus* Waag.),
      ,, aff. *claviger* (Waag.);

Nautiloidea.—
   Paracenoceras hexagonum (Sow.) (E'.),
      ,, *kumagunense* (Waag.) (M.),
      ,, aff. *lorioli* (v. Loesch) (aff. E'.),
      ,, *wandaense* (Waag.) (B.);

Phylloceratidae.—
   Ptychophylloceras feddeni (Waag.) (M.),
      ,, *jaraense* (Waag.) (M.),
   Calliphylloceras lodaense (Waag.) (M.);

Lytoceratidae.—
   Thysanolytoceras adeloides (Kud.) (M. E.);

Oppelidae.—
   Pseudobrightia dhosaenis Spath,
      ,, *subpunctata* (Spath),
   Campylites secula Spath, (E'.),
   Proscaphites cf. *hermonis* (Noetl.);

Haploceratidae.—
   Lissoceratoides erato (d'Orb.) (E.);

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[1] Equivalent of *Paralleledon egertonianum* Stol. (Himalaya & Aden).

[2] L. F. Spath, *Pal. Ind.*, New Ser , Vol. IX, Mem. 2, Pt. 6, 780 (1927).

Mayaitidae.—

Mayaites maya (Sow.),
,, ,, , var. *aperta* Spath,
,, aff. *maya* (Sow.),
,, *rotundus* Spath,
,, *jumarensis* Spath,
,, *obesus* Spath,
,, *subkobyi* Spath,
,, *smeei* Spath,
,, *radiatus* Spath,
,, (? *Paryphoceras*) *arenosus* (Waag.),
Epimayites polyphemus (Waag.),
,, *transiens* (Waag.) (M.),
,, *lautus* Spath,
,, *subarenosus* Spath,
Dhosaites elephantoides Spath,
,, *otoitoides*-Spath,
,, *primus* Spath,
Paryphoceras rugosum Spath,
,, *badiense* Spath,
,, *stephanoides* Spath,
,, *cocosiforme* Spath
,, *nerunaense* Spath

Perisphinctidae.—

Hubertoceras sp.,
Klematosphinctes praecursor (Waag.),
Alligaticeras indicum Spath,
,, *jooraense* (Waag.) (M.),
,, *obliqueplicatum* (Waag.),
,, *polymorphum* Spath,
Otosphinctes rota (Waag.),
,, *rotiformis* Spath,
,, *jacki* Spath,
Perisphinctes indogermanus (Waag.) (M. aff E'.),
,, *kheraensis* Spath,
,, *colei* Spath (aff. E'.),
Pachyplanulites subevolutus (Waag.),
,, *nerunaensis* Spath, (E'.)

Aspidoceratidae.—

Peltoceratoides semirugosus (Waag.) (=*P. arduennensis*, M. K.)
,, ,, , var. *densicostata* Spath
,, ,, , var. *robusta* Spath,
,, *inconstans* (Uhl.) (E'.),
,, *indicus* Spath,
,, *bidens* (Waag.),
,, *propinquus* (Waag.),
,, aff. *eugenii* (Rasp.) (aff. E'.),
,, *aegoceroides* (Waag.),
,, (*Parawedekindia* ? aff. *torosus* (Opp.) (aff. E'.)
Euaspidoceras waageni Spath,
,, *obesum* Spath,
,, *sparsispinum* (Waag.),
,, *blakei* Spath, Blakei,
,, *jumarense* Spath,
,, *neumayri* Spath,
,, *cornutum* Spath,
,, aff. *ovale* (Neumann) (aff. E'.),
,, *simile* Spath,
,, *badiense* Spath,
Paraspidoceras aff. *loricatum* Spath (aff. E'.).

At Jumara, Jarra and Surka, a higher green oolite has been noted with a distinct fauna of its own; from this Upper Dhosa Oolite have been obtained :

CEPHALOPODA—

Oppelidae.—
Taramelliceras jumarense Spath.

Perisphinctidae.—
Dichotomosphinctes helenae (de Riaz), (E'.),
,, *subhelenae* Spath,
Discosphinctes aff. *virgulatus* (Quenst.) (aff. E'.),
,, aff. *kreutzi* (Siem.) (aff. E'.),
(*Lithacoceras*) *submazuricus* Spath (=*Perisphinctes chloroolithicus* Waag. non Gumbel).

Aspidoceratidae.—
Euaspidoceras (*Neaspidoceras* ?) sp.

Besides the cephalopods, the following have been recorded by Dr. Spath, most of them from the matrix of large examples of *Mayaites* : *Pleurotomaria* spp., *Vermetus* sp., *Lopha* sp., *Pecten* spp., *Vola* sp., *Inoceramus* sp., *Pinna* sp., *Myoconcha* sp., *Pleuromya* sp., *Pholadomya* sp., *Trigonia nitida* Kitch., *Astarte unilateralis* Sow., *A. compressa* Sow., *Rhynchonella pauciplicata* Kitch., *R. subplicatella* Kitch., *R. fornis* Kitch., *R. brevicostata* Kitch., *R. versabilis* Kitch., *Terebratula dhosaensis* Kitch and var., *T. compressa* Kitch., *T. euryptycha* Kitch[1]., fossil wood is recorded. From the Lower Dhosa Oolite Dr. L. R. Cox has recognised : *Grammatodon* (*Indogrammatodon*) *virgatus* (Sow.), *Modiola glendayi* (Weir), *Pteroperna* sp. and *Oxytoma inaequivalve* (Sow.), the last being a form found in Europe and British Somaliland.

Katrol series.—The Katrol series, which rests upon the uppermost subdivisions of the Chari beds, is of considerable thickness. It consists of sandstones of various kinds, white, brown, pinkish grey, etc., and shales which are usually grey or reddish but are sometimes very dark coloured like those of the Anceps Beds. Shales prevail towards the base of the group and sometimes contain ferruginous nodules and concretions. Although shales on the whole predominate, the upper portion is composed largely of sandstones.

Kantkot Sandstones.—In Cutch proper the Katrol series forms two belts. The first extends for nearly eighty miles in the anticline along the Rann, occupying the median range, surrounding the inliers of the Pachham and Chari series and stretching to a considerable distance beyond them ; this exposure varies in breadth within a maximum of nearly ten miles. The second belt, situated in the Charwar range south of the great fault, is about 35 miles from east to west, but nowhere more than two miles broad. In addition, the greater part of Wagur is occupied by beds which have been assigned to the base of the Katrols but which might equally well be given a place to themselves intermediate between the Chari and Katrol. From their development around the town of Kantkot, these Wagur beds have received the name of Kantkot Sandstone ; they are composed of grey or yellowish shales below, and of white, grey and pinkish sandstones, both coarse and fine, above. Although the Wagur rocks are very similar in mineral character to the Katrol rocks of the Cutch main area, their cephalopoda are almost all distinct and indicate a lower horizon. The cephalopods include :

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[1] "*Terebratula sella* var". Sowerby.

- Belemnoidea.—
  - *Belemnopsis kuntcotensis* (Waag.),
  - *Hibolites fusticulus* (Waag.),
  - ,, *stoliczkanus* (Waag.).
- Phylloceratidae.—
  - *Ptychophylloceras insulare* (Waag.).
- Oppelidae.
  - *Taramelliceras* sp.
- Mayaitidae.—
  - *Epimayaites lemoinei* (Spath) (=*Stephanoceras* cf. *maya* from Spiti),
  - ,, *axonoides* Spath,
  - ,, *subtumidus* (Waag.),
  - ,, *pseudindicus* Spath,
  - ,, *evolutus* Spath,
  - ,, *excentridus* Spath,
  - ,, *transiens* (Waag.),
  - ,, *falcoides* Spath,
  - ,, *patella* Spath,
  - *Prograyiceras grayi* (Spath) (=*Sephanoceras nepalense* from Spiti),
  - ,, *tramaunense* Spath.
- Perisphinctidae.—
  - *Klematosphinctes* aff. *hiemeri* (Opp.) (aff. E'.),
  - *Perisphinctes orientalis* Siem. (E'. ?=*P. plicatilis* (Dorn))
  - *Biplices wagurensis* Spath,
  - ,, (?) aff. *böhmi* (Steinm.),
  - *Pachyplanulites subevolutus* (Waag.) (K.),
  - ,, *pagri* (Waag.),
  - ,, *subcolubrinus* (Waag.) (K.),
  - *Dichotomosphinctes orbignyi* (P. de Lor) (E'.),
  - ,, *falculae* (Ronch.) (E'.),
  - ,, *helenae* (de Riaz) (E'.),
  - ,, *grossouvrei* (Siem) (E'.),
  - ,, cf. *subrota* (Choff.) (cf. E'.),
  - ,, aff. *luciae* (de Raiz) (aff. E'.),
  - *Prososphinctes virguloides* (Waag.) (K.),
  - ,, (?) aff. *fontannesi* (Choff.) (aff. E'.),
  - *Ataxioceras praecox* Spath,
  - ,, *kachhense* Spath,
  - ,, *leiocymon* (Waag.),
  - *Discosphinctes* aff. *aeneas* (Gemm.) (aff. E.),
  - ,, aff. *dybowskii* (Siem.) (aff. E'.),
  - ,, aff. *spongiphyllus* (Moesch) (aff. E'.),
  - ,, (?) *jelskii* (Siem.) (K. E'.),
  - ,, aff. *tyrrhenus* (Gemm.) (aff. E.),
  - ,, aff. *fraasi* (Dacq.) (Species found in Abyssinia),
  - ,, *indicus* (Spath),
  - *Torquatisphinctes torquatus* (Sow.).
- Aspidoceratidae.—
  - *Neaspidoceras tenuispinatum* (Waag.),
  - ,, *wagurense* Spath,
  - ,, *varians* Spath,
  - ,, aff. *lusitanicum* (Choff.) (aff. E'.),
  - *Euaspidoceras subdistractum* (Waag.).

Probably the whole of the Kantkot Sandstone stage belongs to the Argovian (*transversarius* and *bimammatus* zones).

In the scarp at Iddurghur Mr. J. H. Smith has collected two ammonites identified by Dr. Spath as *Planites* aff. *ernesti* de Lor. and *Torquatisphinctes* sp., and from beds 10 feet higher up four fragments recognised as *Ataxioceras* ? (*Planites* ?) sp. ind., *Torquatisphinctes* sp. *nov.* ? ind., *Planites* aff. *breviceps* Quenst. (*Perisphinctes lictor* Canav. *non* Forntannes) and a form resembling *Perisphinctes modestus* Schneid. These ammonite faunas, according to Spath, approximate to that of the Kantkot. The interesting point of the occurrences, however, is the discovery by Mr. J. H. Smith, in the lower of the two horizons of a lamellibranch assemblage[1] very similar to one which has hitherto been regarded as a typical feature of the Umia series at the top of the Jurassic sequence. The specimens from Iddurghur include *Astarte major* Sow., *Gervillia kantkotensis* Cox, *Exogyra* cf. *imbricata* Krauss, *Pinna* sp., *Chlamys* ? sp., the large *Grammatodon* (*Indogrammatodom*) *iddurghurensis* Cox, and *Trigonia smeei* Sow.[1]

A fauna from Gangta Bet, also of Argovian age, includes[2] *Perisphinctes jelskii* Siem., *P.* aff. *inconstans* (Spath), *P.* aff. *orientalis* Siem., *Prososphinctes virguloides* (Waag.), *Discosphinctes* aff. *virgulatus* (Quenst.), *Torquatisphinctes* cf. *torquatus* (Sow.), *Epimayaites* sp., *Astarte major* Sow. and an eogyrate oyster.

Jurun Beds.—Another small fauna from the Belemnite Marls of Jurun includes not a single species known either from the Kantkot Sandstone or from the basal Katrol bed of southern Cutch ; if there be any Lower Kimmeridgian at all in Cutch, it must, in the opinion of Dr. Spath, be represented by at least some of this assemblage. The fauna includes.[3]

CEPHALOPODA—
Torquatisphinctes alterneplicatus (Waag.),
,, ,, ,, , var. *maculata* Spath,
,, *jurunensis* Spath,
,, *similis* Spath,
,, sp. (transitional to *Pachyplanulites irregularis*),
Planites consociatiformis (Sim.),
,, aff. *breviceps* (Quenst.),
Metahoploceras pascoei Spath,
,, aff. *kobyi* (Choff.),
,, sp. (*pseudoflexuosum* Coff., *non* Favre),
Holcophylloceras mesolcum (Dietr.),
Aspidoceras asymmetricum Spath,
,, aff. *bispinosum* (Ziet.), (aff. E').,
Hibolites spp. (*hastatus-claviger* group).

Lower Katrol Stage.—The earliest fauna of the Katrol series proper has been collected mostly from the basal "Katrol Ammonite bed" of Fakirwadi and Ler and the neighbouring localities in the southern range ; preserved in a dark, phosphatic grit weathering almost white, the ammonites are generally easy to recognise. A few of the specimens come from Habye. The fauna of the basal Katrol bed appears to Dr. Spath to belong to the Middle rather than to the Lower Kimmeridgian ; it includes :

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[1] *Geol. Mag.* LXXII, 186 (1935) ; *Pal. Ind.* Ser. IX, Vol. III, Pt. 3, (1940). Spath records *Trigonia smeei* and *Astarte major* from Kantkot, but whether from the Kantkot Sandstone or from some other horizon at Kantkot is not stated (*Ibid.* 186-7). In Wagur the Kantkot Sandstone is overlain by beds which are similar lithologically but which contain only lamellibranchs including *Astarte major* and *Trigonia smeei*. Other examples are suspected of a similar lamellibranch fauna occurring at much the same horizon and considerably below that of the Umia group; such include, besides the *Trigonia* and *Astarte* mentioned, *Ostraea marshi* Sow., *Gryphaea dilatata* Sow., and perhaps *Trigonia tenuis* Kitch. *T. trapeziformis* Kitch. and *T. remota* Kitch. (*Pal. Ind.*, New Ser., vol. IX, Mem. 2, 786-787 (1927)). Dr. L. R. Cox also records the following : *Grammatodon* (*Indogrammatodon*) *kantkotensis* Cox from the Argovian of Kantkot ; *Mytilus* (*Falcimytilus* ?) *tramauensis* Cox from the Argovian of the Tramau river ; and *Oxytoma inaequivalve* (Sow.) from the Upper Argovian of Barodia.

[2] L. F. Spath. *Geol. Mag.* Vol. LXXII, Note 3, p. 186 (1935).

[3] *Ibid.* Note 1, p. 187 (1935).

CEPHALOPODA—

Belemnoidae.—

Belemnopsis aff. *tanganensis* (Futt.) (Species M. and Somaliland),
Hibolites cf. *semisulcatus* (Munst.) (cf. E.),
,, *katrolensis* (Waag.) (M.),
,, *claviger* (Waag.).

Phylloceratidae.—

Phylloceras saxonicum Neum. (E.),
Ptychophylloceras ptychoicum (Quenst.) (E. & Tanganyika).,
Calliphylloceras benacense (Cat.) (E.),
Holcophylloceras polyolcum (Dietr.),
Sowerbyceras loryi (Mun.-Chal.) (E.).

Oppelidae.—

Taramelliceras kachhense (Waag.),
,, *akher* Spath,
,, cf. *compsum* (Opp.) (cf. E'.),
,, aff. *holbeini* (Opp.) (aff. E'.),
,, aff. *franciscanum* (Font.) (aff. E.),
,, *gibbosum* Spath,
,, aff. *succedens* (Opp.) Zitt. sp. (cf. E.),
,, *pseudoflexuosum* (Favre) (E.),
,, *transitorium* Spath,
,, *planifrons* Spath,
,, *nereiforme* Spath,
,, *subkobyi* Spath,
Streblites plicodiscus (Waag.),
,, *leptodiscus* Spath,
,, *habyensis* Spath,
Hemihaploceras nobile (Neum.).

Haploceratidae.—

Glochiceras deplanatum (Waag.),
,, aff. *dentatum* (Rein.) (aff. E'.),
,, cf. *fialar* (Opp.) (cf. E'.),
,, aff. *somalicum* Spath.

Perisphinctidae.—

Dichotomoceras predivisum Spath,
Biplices anguinus Spath,
,, (?) *auritus* Spath,
Pachyplanulites irregularis Spath,
Lithacoceras preudovirguloides Spath,
Torquatisphinctes alterneplicatus (Waag.) var. *neglecta* Spath,
,, *primus* Spath,
,, *acuticostatus* Spath,
,, *tenuistriatus* Spath,
,, (?) *lunulatoplicatus* Spath.

Aspidoceratidae.—

Pseudowaagenia haynaldi (Herb.) Neum. sp. (E. cf. M.),
,, *carpathica* Spath (E.),
,, *micropla* (Opp.) (E.),
Aspidoceras aff. *sesquinodosum* (Font.) (aff. E.),
,, aff. *pseudomicroplum* (Burckh.),
,, aff. *longispinum* (Sow.) (aff. E'.),
,, *caroli* Spath,
,, *binodum* (Quenst.) Opp. sp. (cf. E'.),
Waagenia monacantha (Waag.) (Some of the Cutch species common to Somaliland)
,, *kachhensis* Spath, (M.),
,, *hildebrandti* (Beyr.) Futt. (M.),
,, *beckeri* (Neum.) (E.),
,, *ornata* Spath.

Phylloceratids for the first time appear in large numbers, all four of the great groups being represented. The main features of the fauna are: the increase in the number of species of oppelids and aspidoceratids, the comparative rarity of perisphinctids other than *Torquatisphinctes*, and the complete absence of ***Euaspidoceras*** and *Ataxioceras*.[1]

Middle Katrol Stage.—Above the basal Katrol phosphatic grit and accompanying shales there follow various brown and red ironstones, from somewhat varying horizons of which has been collected a fauna intimately allied to the Lower Katrol assemblage and corresponding approximately to the European *Steraspis.* zone or *Gravesia* beds of the Middle Kimmeridgian. The abundance of *Pachysphinctes* and *Katroliceras* is the most notable feature of this Middle Katrol assemblage which includes :

CEPHALOPODA—
Phylloceratidae.—
Ptychophylloceras ptychoicum (Quenst.),
Holcophylloceras mesolcum (Dietr.) (E. & Tanganyika),
Lytoceratidae—
Hemilytoceras rex (Waag.),
Oppelidae.—
Streblites plicodiscus (Waag.),
Aptychus (*Lamellaptychus*) *euglyptus* Opp. (E'.),
Perisphinctidae.—
Torquatisphinctes intermedius Spath,
,, *habyensis* Spath (K.),
,, *ruber* Spath,
Pachysphinctes major Spath (K.),
,, *robustus* Spath,
,, *granti* Spath,
,, *crassus* Spath,
,, *bathyplocus* (Waag.) (Badesar beds of Rajputana),
,, ,, , var. *sparsicostata* Spath,
,, ,, , var. *serpentina* Spath,
,, ,, , var. *obesa* Spath,
,, *linguiferus* Spath,
,, *wantraensis* Spath,
,, *symmetricus* Spath,
,, cf. *adelus* (Gemm.) (cf. E.),
,, *orientalis* Spath,
Subplanites elegans Spath,
,, *adeloides* Spath,
,, ,, , var. *rotunda* Spath,
,, aff. *contiguus* (Cat.) Zitt. sp. (aff. E.),
,, (?) *flexuosus* Spath,
Metagravesia decipiens Spath,
Katroliceras pottingeri (Sow.),
,, ,, , var. *obtusifrons* Spath,
,, *waageni* Spath,
,, *sowerbyi* Spath,
,, ,, , var. *difficilis* Spath,
,, *lerense* Spath,
,, *euplocum* (Waag.).
,, *zitteli* Spath,
,, *arenosum* Spath,
,, *depressum* Spath,
,, ,, , var. *peltos* Spath,
,, *pingue* Spath,
,, *subkatrolense* Spath,
,, ,, , var. *splendens* Spath
,, *katrolense* (Waag.),
,, ,, , var. *spissiplicata* Spath,
,, (?) *pallasiforme* Spath,
Subdichotomoceras inversum Spath,
,, *simplex* Spath,
Aulacosphinctoides latedorsatus Spath,
,, *kachhensis* Spath,
,, cf. *intermedius* (Uhl.),

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[1] L. F. Spath. *Pal. Ind.*, New Ser., Vol. IX, Mem. 2, Pt. 6, 759 (1972)

Aspidoceratidae.—
Aspidoceras lerense Spath,
,, aff. *hoplisum* (Opp.) (aff. E.),
,, *iphiceroides* (Waag.) (M.),
,, *binodiferum* (Waag.),
,, *wynnei* (Waag.) (K.),
,, *subwynnei* Spath,
Physodoceras (?) aff. *avellanum* Zitt. (aff. E.),
Waagenia kachhensis Spath, (M.),
,, *ornata* Spath.

Upper Katrol Stage or Gajansar Beds.—It will be seen that some four of the ammonites listed above occur at higher levels, but about 200 feet above the upper limit of the Dhosa Oolite ammonites have all but disappeared. The Middle Katrol beds with their fossils are followed first by barren shales and then by a great thickness of Katrol sandstone equally devoid of ammonites. A fauna believed to be younger than the Katrol faunas so far considered, but older than the Tithonian Umia assemblage, has been described by Dr. Spath from Gajansar (Gudjinsir), where the equivalents of the Kantkot Sandstone and the Jurun Belemnite Marls are wanting. The rocks, from which this Upper Katrol fauna has been collected rest directly upon the local Dhosa Oolite and have yielded:

Cephalopoda—
Belemnoidea.—
Belemnopsis cf. *gerardi* (Opp.) Uhl.,
Nautiloidea.—
Paracenoceras hexagonoides Spath,
Phylloceratidae.—
Phylloceras cf. *plicatum* Uhl.,
,, cf. *consanguinum* Genm. (cf. E.),
Ptychophylloceras angelini (Opp.) Zitt. sp. (E.),
,, *geminum* (Ben.) (E.),
,, aff. *zignii* (Opp.) Zitt. sp. (aff. E.),
Holcophylloceras mesolcum (Dietr.),
Oppelidae.—
Streblites gajinsarensis Spath,
Haploceratidae.—
Haploceras elimatum (Opp.) (M. E. Tanganyika),
Hildoglochiceras propinquum (Waag.) (?)M.,
,, *subdieneri* Spath,
,, ,, , var, *laevis* Spath,
,, *planum* (Waag.),
,, *colei* Spath,
,, ,, , var. *falcifera* Spath,
Perisphinctidae —
Subdichotomoceras (?) *sparsiplicatum* (Waag.) (Tanganyika),
,, (?) *gajinsarense* Spath,
,, (*Aulacosphinctoides* ?) *diadema* Spath.

This fauna is not unlike that of the *Trigonia smeei* beds in the Tendaguru-series of Tanganyika which contains Portlandian ammonites ; it shows resemblances also to the glauconitic sandstones of the same age at Antsalova in Madagascar.[1]

Probably from some ironstone band in the Upper Katrol, perhaps from a higher horizon than the above come the two forms : *Aulacosphinctoides meridionalis* Spath, and *Virgatosphinctes* (?) *indosphinctoides* Spath.

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[1] *Ann. S. Afr. Mus.*, XXVIII, Pt. 2, 131 (1930).

The Zamia Shales of Narha.—In the Katrol series proper, imperfect plant remains are common, as they are in many of the lower beds of the Cutch Jurassics, but in one instance, near the village of Narha (Nurrha) some of the plants are more or less determinable and have been discussed in the chapter on the Gondwana system (p. 993). Associated with these plant remains in the Zamia Shales of Narha is a small marine fauna, probably of much the same age as that of the Gajansar beds; it consists of:

CEPHALOPODA.—
Hildoglochiceras kobelli (Opp.) (M. Spiti and Tanganyika),
,, *kobelliforme* (Par. & Bon.),
Dorsoplanites mirabilis Spath,
Oecoptychius refractus (Rein.) (E'.).

The last species has also been obtained at Jarra from a bed said to be 600 feet above the Dhosa Oolite.

A *Pleurotomaria*, a *Pholadomya*, an *Inoceramus*, a *Stomechinus*, *Cidaris* sp., *Pseudodiadema* sp. and a few pieces of wood are also recorded from the Katrol series.

Umia series.—Taken as a whole, the Umia series, called after a small village in western Cutch, is upwards of 3,000 feet thick and equal in development to nearly all the Jurrasic beds below it. As a rule it consists of sandstones of various kinds, and more or less sandy shales. The sandstones are usually soft and white or pale brown in colour, occasionally variegated with pink, red and often very argillaceous with a tendency to decompose into a loose sandy soil which covers and conceals outcrops over a great part of the country. Among the sandstones are a few thin, hard bands approaching quartzite and, much more frequently, thin bands of hard, black or brown, ferruginous grit. In a few instances carbonaceous shale occurs, and in one locality a thin seam of bright jetty coal. The beds of this series, in fact, show a marked resemblance to some of the Upper Gondwana strata of Central India, especially the soft, argillaceous sandstones and sandy shales and the hard, ferruginous, gritty bands. The presence of glauconite in some oolites which form part of the Umia succession suggests slow sedimentation.

The surface occupied by the rocks of the Umia series corresponds in magnitude with the thickness of the formation and embraces about half the Jurassic area in Cutch. In Cutch proper these beds extend throughout the province from the northwestern extremity near Lakhpat to the eastern end beyond Bachao, forming a great plain south of the irregular range of hills along the edge of the Rann. They also reach round each end of the range, especially to the east where the bottom Umia beds stretch north of the hills for about 20 miles along the edge of the Rann. The main belt of the Umia beds is, on an average, from eight to twelve miles across. The rocks lap round the western end of the Charwar range, where the large E.-W. fault, to which the range appears to be largely due, seems to die out; south of the Charwar range they cover another plain, nearly 50 miles in length from east to west and about eight miles broad. Umia rocks also occupy the western portion of Wagur.

The beds of the Umia series are covered unconformably by the Deccan traps and by Tertiary rocks except in one place in northwestern Cutch, where they underlie the Lower Cretaceous strata of Ukra hill.

Towards the base of the Umia series there is a thick band of hard, grey, calcareous conglomerate, sometimes ferruginous, associated with sandstones and shales. In this conglomerate and in some of the associated beds marine fossils are numerous. Throughout the rest of the group plant remains are common, though not often sufficiently well preserved to be identified. Except in the basal bed, marine fossils are rare in the Umia series but, separated from the Lower Umia scarps with their Tithonian ammonites by ridges of barren sandstones 200-300 feet thick, is a *Trigonia* bed[1] which is capped by about 1,000 feet of Upper Umia shales and sandstones ; next in succession follow the remnants of marine Aptian beds at Ukra Hill, but it is possible that they are cut off from the older beds by a fault[2]. *Trigonia smeei* Sow., the most typical fossil of the series, is said to have been found in some places, as for instance near Vigori, forty miles northwest of Bhuj, in beds near the top and well above the horizon at which most of the fossil plants have been obtained. From the Umia group there has been obtained the fragment of a mandible of *Plesiosaurus* described as *P. indicus*, whose affinities are not fully determinable[3].

The basal Umia bed has yielded the followings cephalopod fauna, which is more homogeneous than the faunas of the beds below and indicates at the latest a Lower Tithonian or even possibly an uppermost Portlandian age :

CEPHALOPODA—

Belemonoidea.—

Belemnopsis sp.
Hibolites aff. *claviger* (Waag.),

Nautiloidea.—

Paracenoceras hexagonoides Spath,

Phylloceratidae.—

Ptychophylloceras tithonicum Spath,
Holcophylloceras silesiacum (Opp.) (E.),

Lytoceratidae.—

Hemilytoceras of. *montanum* (Opp.) (cf. E.),
,, aff. *sutile* (Opp.) (aff. E.),

Haploceratidae.—

Haploceras sp.

Perishphinctidae.—

Aulacosphinctoides (?) sp.
Virgatosphinctes denseplicatus (Waag.) (Himalaya),
,, ,, ,var. *inaequalis* Spath,
,, ,, ,var. *blakei* Spath,
,, ,, ,var. *rotunda* Spath,
,, ,, ,var. *striatissima* Spath,
,, *communis* Spath,
,, *oppeli* Spath, (aff. a Badesar form, Rajputana ; equivalent to *Perisphinctes frequens* of Spiti),
,, *saheraensis* Spath,
Aulacosphinctes occultefurcatus (Waag.) (of. E'.),
Micracanthoceras aff. *microcanthum* (Opp.) (Species E.),
,, *brightoni* Spath,
,, aff. *fraudator* (Zitt.) (aff. E.),
Umiaites rajnathi Spath,
,, *minor* Spath.

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[1] *Ann. S. Afr. Mus.* XXVIII, pt. 2, 131 (1930).

[2] Mr. Raj Nath places the Ukra beds between a restricted Umia series including the ammonite bed, the Trigonia beds and about 1,000 feet of unfossiliferous shales below, and the Zamia beds and Plant beds which he unites into the "Bhuj stage" above ; this however, would make the Zamia beds and Plant beds Middle Cretaceous. (*Q. J. Geol. Min. Met. Soc. Ind.*, IV, 167 (1932).

[3] R. Lydekker, *Rec.* XX,67 (1887).

For correlation purposes the presence of *Micracanthoceras* is important, while the predominance of the genus *Virgatosphinctes* is also significant.

Cephalopoda are described as exceptional in the Umia series and as forming by no means so important a proportion of the fauna as they do in the other Jurassic subdivisions, the most typical fossils being two species of *Trigonia* (*Trigonia smeei* and *T. ventricosa*) and an *Astarte* (*A.* "*major*"). That some of the forms belonging to the lamellibranch horizon occur in the ammonite bed also is proved by the discovery by Dr. Spath of numerous specimens of the brachiopod, *Acanthothyris multistriata* Kitch., an example of *Trigonia retrorsa* Kitch., and a very large *Pecten* (*Chlamys* or *Aequipecten*) resembling some Tertiary types, all adhering to the matrix of one of the gigantic *Virgatosphinctes* from the Umia ammonite bed. As we have seen, a very similar lamellibranch bed has every appearence of belonging to a horizon close to that of the Kantkot sandstone, and one conclusion is that some of the lamellibranchs range at least from the Kantkot Sandstone to the Umia.

It remains to describe briefly the non-cephalopod fauna assigned to the Umia series. Whether there has been any confusion between collections from the Kantkot lamellibranch horizon and those from the similar horizon in the Umia series, it is not possible to say ; if not, it merely follows that still more of the non-cephalopod forms have a longer vertical range than was at first supposed. The commonest Umia fossils are described as *Trigonia smeei* Sow, and *T. ventricosa* Krauss. The latter is recorded from the Margalla Pass of Hazara, where it occurs in profusion in rocks considered to be the equivalents of the Giumal Sandstone of Spiti[1] whilst the occurrence of both forms in Upper Gondwana strata (Tripati beds) near Rajahmundry in Madras has already been noted (p.1002). A form described as *T. tuberculifera* Stol. from the Cretaceous (Trichinopoly) beds of Coonnum in Madras is either very closely allied to or identical with *T. ventricosa*[2]. Still more interesting, however, is the occurrence of *Trigonia ventricosa* in the Uitenhage series (Cretaceous) of South Africa and in Lower Neocomian beds in Tanganyika (old German East Africa, N. W. of Kiswere). On the Sunday river at Prince Alfred's Rest in South Africa *Trigonia ventricosa* is accompanied by *T. vau* Sharpe, a peculiar Uitenhage species whose adult forms resemble mature specimens of the Umia *T. v-scripta* Kitch., this resemblance, however, is regarded as an interesting case of convergence in development, their adolescent characters being widely different. The costate section of the *Trigonia*, which played such an important part in the older Chari beds is replaced in the Umia beds by non-costate types, though relics of the older section are seen in the presence of *T. parva* Kitch. and *T. tenuis* Kitch., both costate forms ; *T. smeei* is an interesting link between the two sections. Other species of *Trigonia* from the Umia beds as determined by Dr. Kitchin, are : *T. crassa* Kitch., almost identical with the Tanganyika form, *T. beyschlagi* Mull.[3] *T. cardiniformis* Kitch., *T. trapeziformis* Kitch., *T. retrorsa* Kitch., *T. spissicostata* Kitch[4]., *T. dubia* Kitch., *T. recurva* Kitch., *T. remota* Kitch., *T. mamillata* Kitch., a form generally resembling *T. herzogi* Hausm. and *T. pulchra* Kitch. A species of *Seebachia*, a South African Uitenhage genus, is another interesting member of this fauna. Other forms of common occurrence, some of them ranging into lower groups, are

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[1] A. B. Wynne. *Rec.* XII, 125 (1879).

[3] F. L. Kitchin. *Pal. Ind.*, Ser. IX, Vol. III, Pt. 2, 106 and 108, (1900). *Ibid.*, Ser. VI, Vol. III 315 (1870-71).

[3] *Pal. Ind.*, Ser. IX, Vol. III, pt. 2, Appendix, 121.

[4] Originally described as *T. gibbosa*.

Astarte major Sow., *Gervilla anceps* Desh., a species found also in Europe, Tanganyika, Zululand and Argentina, a peculiar *Gryphaea* intermediate in character between *G. vesicularis* and *G. dilatata*, *Goniomya*, etc. Dr. Spath notes the presence of *Acanthothyris multistriata* Kitch., a very large *Chlamys* or *Aequipecten* and many massive *Cucullaea* with examples indistinguishable from *C. kraussi* Tate. More recently Dr. L. R. Cox has definitely identified *Cucullaea* (*Megacucullaea*) *kraussi* Tate., a form found in the Uitenhage of south Africa and the Tendaguru Necomian of Tanganyika, *C.* (*M.*) *eminens* Cox. and *Lithophaga* sp.

A portion of the jaw of a sauropterygian, *Thaumatosaurus indicus*, also obtained from these beds, it is said to be indistinguishable from that of *Thaumatosaurus* (*Plesiosaurus*) *arcuatus* Owen, from the Lower Lias of England.[1] From the basal 50 feet comes the coral *Stylina*. [2]

The plant remains of the Umia series and their relations have already been described in the chapter on the Gondwana system. They were at first thought to indicate an age equivalent to that of the Lower Oolites of Yorkshire, but later diagnoses have assigned them either to the uppermost Jurassic or the base of the Neocomian.

KATHIAWAR AND BARODA.

The so-called Umia beds of Kathiwar contain no marine fossils and have been considered under the heading of Gondwana. The Songir sandstone of Baroda also finds mention there (p. 997.).

RAJPUTANA.

General Succession.—A few Jurassic fossils are reported to have been found by Sir H. Pottinger in the desert country immediately north of the Rann of Cutch but no stratigraphical details are available. Further north in the Jaisalmer State of Rajputana five distinct groups of rocks have been recognised and named as follows.

5. Abur Beds. Cretaceous (Aptian).
4. Parihar Sandstones. Some part of the sequence, Upper Tithonian—Neocomian.
3. Bedesar Sandstones. Jurassic; Kimmeridgian-Tithonian.
2. Jaisalmer Limestones. Jurassic; Upper Callovian-Argovian.
1. Lathi series. Gondwana.

The plant-bearing, fresh-water Lathi series, which belongs to the Gondwana system and may possibly trespass into the Jurassic, has already been described. This succession of ferruginous sandstones is overlain by four successsive formations, three of which must be considered here.

Jaisalmer Limestone.—The Jaisalmer series is exposed around the town of Jaisalmer along the northwestern border of the Lathi outcrop and is followed further to the northwest, successively but irregularly, by the Bedesar (Bedesir; Bhadasar) series, the Parihar series, the Abur series and finally by the Nummullite Limestone which unconformably overlaps the two last to rest upon the Bedesar sandstones.

The Jaisalmer series, traversed by the Karkana *nala*, a watercourse which has a length of 45 miles and is ultimately lost in a salt plain that becomes a shallow lake during the rains [1] consists of thick bands of buff-coloured compact limestone, interstratified with grey, brown and blackish sandstones containing some conglomerate. The limestone forms conspicuous scarps close to the town of Jaisalmer and is highly fossiliferous. Amongst other species the following fossils are recorded by Mr. R. D. Oldham: *Terebratula biplicata* Sow., *T. intermedia* Sow., *Pholadomya granosa* Sow., *Corbula lyrata* Sow., *C. pectinata* Sow., *Trigonia costata* Sow., *Nucula cuneiformis* Sow., *Pecten lens* Sow., and *Paracenoceras* (*Nautilus*) *kumagunenses* (Waag). Several cephalopod zones are present in the Jaisalmer limestones but have not yet been described in detail. Among the ammonites Dr. Spath has identified the Cutch form, *Idiocycloceras singulare* Spath (identical with some of the specimens of Waagen's *Stepharoceras fissum* though not with Sowerby's type,[2] an indication of the presence of the Anceps beds of the Cutch succession. The same authority has also recognised *Sindeites sindensis* Spath (a species found also in Kenya), *Reineckeia* cf. *reissi* Stenim., *Grossouvria steinmanni* Par. & Bon., *Obtusicostites* sp., and a doubtful *Properisphinctes* aff. *bernensis* P. de Lor., from which the presence of both the Anceps and Athleta beds of the Chari series is deduced[3]. A higher horizon is represented by some half-dozen badly preserved ammonites in a matrix of grey limestone with brown oolite grains. They include perisphinctids of the *Prososphinctes* type, *Torquatisphinctes* (?) of the *jelskii*-group and a doubtful, badly worn oppelid (?) *Campylites*. Such as it is, this meagre fauna is close to that of the Dhosa Oolite, but perhaps still closer to that of the Kantkot Sandstone (Upper Oxfordian). The Jaisalmer limestones, therefore, would appear to embrace at least the Middle and Upper Chari and the Kantkot Sandstone stages of Cutch.[4]

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[1] R. Lydekker *Rec.* XXII, 49-51 (1889).

[2] Raj Nath. *Q. J. Geol. min. met. Soc. Ind.*, Vol. IV, 176 (1932).

Bedesar Sandstones.—The Jaisalmer limestones are overlain by a group of pale purplish and reddish sandstones, with thin layers of black, vitreous, ferruginous sandstones, and some beds of a red, calcareous variety. The ferruginous bands form partings in the softer sandstone, seldom more than $\frac{3}{4}$th inch thick and never exceeding a proportion of 1/30th of the whole thickness of beds. The extreme hardness of the rock forming these bands makes it almost immune from the attacks of the weather and, wherever it occurs, its fragments thickly strew the ground and give the country a desolate aspect not unlike that of a cinder heap or of a recent lava flow on which vegetation has not had time to establish itself. The rocks of this series, the Bedesar Sandstones, form a prominent scarp 100 feet high, northwest of the Jaisalmer limestones outcrop, from which throughout part of the boundary they are separated by a fault.[5] The red, calcareous sandstones contain fossils, some of which are said to resemble closely forms from the Katrol series of Cutch. Two ammonites collected by Mr. R. D. Oldham from a locality $2\frac{1}{4}$ miles northwest of Lodorva, a village eight miles northwest of Jaisalmer town, have been identified as *Pachysphinctes* aff. *bathyplocus* (Waag.) and *Virgatosphinctes* sp., embedded in different matrices; from the scarp west of the village he collected also two examples of *Virgatosphinctes* aff., *oppeli* Spath, of typical Umia aspect and with the characteristic quartz pebbles in the matrix. The Bedesar series, therefore, must be correlated with Umia ammonite bed and probably includes at least the upper part of the Katrol series.

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[1] R. D. Oldham. *Rec.* XIX, 158 (1886).

[2] *Pal. Ind.* New Ser., Vol. IX, Mem. 2, 799 (1933).

[3] *Pal. Ind.* New Ser., Vol. IX, Mem. 2, 800 (1933).

[4] Dr. M. R. Sahni and Mr. N. C. Bhatnagar have investigated a Callovian fauna from Jaisalmer, including the following:
Jaisalmeria taylori Sahni and Bhatnagar., *J. depressa* Sahni and Bhatnagar., ? *Kutchithyris jaisalmerensis* Sahni and Bhatnagar., *Hemicidaris jaisalmerensis* Sahni and Bhatnagar.,
(Current Science, Vol. 24, No. 6, June 1955; *Rec.* LXXXVII, pt. 2, (1953).)

[5] T. H. D. Latouche *Mem.* XXXV, Pt. 1, Map, (1902).

Parihar Sandstones.—The Bedesar sandstones are in one section overlain by, in another in faulted contact with, the Parihar group of soft, white, felspathic sandstones, which weather into a clean, sugary sand largely composed of subangular fragments of transparent quartz. The Parihar hills are formed of a glassy, quartzitic type of sandstone, rising from the plain flat country produced by the more easily weathered variety. The boundary with the subjacent Bedesar series is not very definite. Lithologically the Parihar series is said very closely to resemble the Umia beds of Cutch, but no fossils of any kind have so far been reported, and to what extent this series bridges the gap between the Bedesar below and the Cretaceous Abur beds above, or to what part of the gap it belongs, it is impossible to say.

An interesting feature in Rajputana and Idar, deserving of mention under the present heading, is the level line formed by the summits of many of the ridges from Alwar in the northeast to Idar in the southwest. This level is highest to the west of the Ajabgarh valley and falls steadily to the north and east in the same direction as does the level of the plain but with a steeper gradient, so that the two levels approach one another. So distinct is this phenomenon that Dr. Heron finds it difficult not to believe that it is an ancient base-level of denudation, upraised and now being re-denuded to a new and lower base level. It is suggested that this old plane of erosion may represent the land surface at the time when the Jurassic and Nummulitic beds of Jaisalmer were being laid down[1]. In Idar this planing of the tops of the hills has been traced to a point 400 feet above the floor of the nearly horizontal Ahmednagar Sandstone, a fluviatile deposit of Lower Cretaceous age.[2] Among the hills which do not reach the height of this hypothetical plane there is no such regularity the crests being of all heights ; though very many of the ridges attain this maximum none ever exceeds it. As Drs. Heron and Ghosh note, the peneplain is thus older than the Ahmednagar Sandstone by a space of time during which 400 feet of quartzites were eroded, but would still probably be Mesozoic in age.

THE SALT RANGE.

The Jurassic is represented in the western parts of the Salt Range, as well as in its trans-Indus continuation, by a very varied and mingled group of arenaceous, argillaceous and calcareous rocks which, by their very liability to marked lateral changes in thickness and composition, preserve an individuality of aspect and can generally be recognised without difficulty. It may be divided into two mutually conformable stages, the Variegated stage below and the Baroch Limestones above, the two together constituting the lower half of Mr. Gee's Isa Khel formation.[3] These Jurassic beds are not found in the easternmost three-quarters of the range.

The Variegated beds first make their appearance in cliffs west of Jalar Lake, a little further west than the commencement of the Triassic Ceratite beds, extending along the southern escarpment of the Son-Sakesar basin where they are interrupted by faults. They reappear in the fine cliffs south of Sakesar summit, on the northern slopes of which mountain they are also exposed. At a point southwest of Sakesar they have rapidly thickened to 300 feet and stretch thence northwestwards to

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[1] *Mem.* XLV ,8 (1917).

[2] *Rec.* 72, 404 (1937).

[3] Mr. E. R. Gee's Memoir on the Salt Range (unpublished).

Khairabad with a few interruptions along the narrow part of the range, increasing in thickness to 500 feet in the Nammal gorge and the Tredian hills ; in the latter area the beds share the general contortion and disturbance.

Wynne describes the lower part of the Jurassic formation as consisting of strong bands of soft, thick-bedded, ferruginous sandstones of red, yellow or variegated colour, alternating in places with liver-coloured and grey ripple-marked varieties. These are followed by thick, yellow, argillaceous limestone, soft, rust-coloured sandstones, grey gypseous and pyritous clays, and soft, powdery sandstones largely composed of white quartz and felspar grains in a white earthy or chalk-like matrix. Among these beds are bands of haematite, several feet in thickness, and thinner layers of a "golden oolite" precisely similar to the Cutch rock and the result of the ferruginisation of an oolitic limestone. Thin layers and small patches of bright, jetty coal occur in places towards the base, but these are merely carbonised fragments of drift wood.

The beds just described form part of Gee's Variegated Beds, a composite stage of alternating shallow-water marine, estuarine or fresh-water, and terrestrial deposits, the base transgressing across the underlying dolomite and sandstones of the Trias. Gee gives the following section in the Nammal gorge as typical of the stage (private communication) :

Variegated sandstones and brownish grey shales . . .	9 feet
Massive, yellowish, grey and ferruginous sandstones . .	40 ,,
Alternating coaly shales and sandstones	4½ ,,
Alternations of massive, soft, grey and brown sandstones, carbonaceous and brownish shales, and hard, yellow calcareous bands	90 ,,
Brownish-grey, massive sandstones, alternating with subordinate shales	42 ,,
Dark red laterite	2½ to 3 ,,
Massive grey and ochreous, felspathic sandstones, alternating with grey and purplish shales, and including in the lower part of the sequence a 4-foot band of carbonaceous shale with layers of harder, yellowish-brown, calcareous sandstones and impure limestones	88 ,,
Yellow arenaceous limestone	2 to 3 ,,
Massive, ochreous, felspathic sandstones, and grey and purplish shales, the latter predominating and including in the lower horizons a dark red laterite zone and two thin bands of coaly shale	150 ,,
Massive, yellowish-grey, gritty sandstones containing small pebbles of quartzite, with carbonaceous and ochreous intercalations characterised by fossil wood and leaf impressions	55 ,,
Sandy, carbonaceous, grey and ochreous shales . . .	6 ,,
Variegated sandstones and shales	6 ,,

The intercalations of carbonaceous shale at several horizons contain carbonised fossil wood and leaf impressions of upper Gondwana type and are usually closely associated with soft, felspathic, white, grey, yellow and variegated sandstones ; springs contaminated with sulphuretted hydrogen characterise the outcrops of some of these beds. In the Tredian hills the laterite horizons, relics of ancient soils, attain in some sections an individual thickness of at least 15 feet ; here also hard, yellowish brown, arenaceous limestone bands containing a few brachiopods form part of the sequence.

The Baroch Limestones, indicating more settled marine conditions, are thin from Sakesar to beyond Nammal, but thicken rapidly to about 220 feet opposite Daud Khel. They are fine in texture, white grey and purplish in colour, with numerous bivalves, most of them ill preserved.

In the neighbourhood of Daud Khel the eroded Jurassics, upon which rest beds with Neocomian fossils, comprise limestones with *Nerinea* sp. and *Rhynchonella* resembling *R. trilobita*; a little lower down the beds have yielded an *Exogyra* comparable with *E. lobata*, and from a still lower horizon come a *Trigonia* resembling a young *T. costata* and a *Cerithium* of Upper Jurassic aspect. A locality to the southwest of Sokan has yielded an assemblage of Tithonian aspect, including[1] :—

- Ammonoidea—
  - *Proniceras indicum* Spath,
  - A prisphinctid (? *Aulocosphinctes*),
  - *Blanfordiceras* aff. *wallichi* (Gray),
  - ,, cf. *acuticostata* (Uhlig),
  - ,, cf. *boehmi* (Uhlig),
  - ,, aff. *latidomus* (Uhlig),
  - *Himalayites* cf. *seideli* (Oppel),
  - *Neocosmoceras* cf. *sayni* (Simion);
- Belemnoidea—
  - *Belemonopsis* cf. *gerardi* (Oppel) Uhligsp.

TRANS-INDUS CONTINUATION OF THE SALT RANGE.

In the Trans-Indus extension of the Salt Range the Jurassic is exposed in the hills north of Kalabagh, and in a continuous outcrop for many miles along the southerly scarp of the Chichali or Maidan hills (Surgarh range). They are well seen in the Chichali Pass, and extend round the curve of the range further to the south than the Productus Limestone does, disappearing beneath the Tertiary rocks about six miles south of Mulla Khel. A small isolated exposure is found in the same range further south, opposite Sultan Khel, another larger outcrop at the southwestern end of the Khasor range, southeast of Paniala, and a third, close to the latter, in the Shekh Budin area of the Nila Roh or Marwat range.

On the west of the Indus the Jurassic rocks have increased greatly in thickness and here also can be divided into a lower arenaceous and an upper calcareous stage, the division being most clearly marked in the more westerly sections, especially at Shekh Budin. Both divisions sometimes contain the characteristic golden oolite seen in the cis-Indus Salt Range, Cutch and the Jurassic rocks of Europe. The lower stage, which is thicker than it is on the east side of the river, is made up of the usual soft, variegated, red and white sandstones, grey shales with numerous obscure plant remains and partings of lignite and coal, and pyritous (alum) shales with subordinate bands of limestones and haematite. The few small seams of coal or lignite occur irregularly distributed in the lower division and have been exploited near Kalabagh, where there are three seams, of a hard, jetty lignite, having a large proportion of sulphur in the form of iron pyrites, and liable to spontaneous combustion.[2] North of Kalabagh, this lower Variegated stage lies upon the Triassic Kingriali dolomite. To the west and south, within the Maidan range the Variegated beds are also well exposed, with bands of dark red haematite shale, some of them as much as 30 feet in thickness; at Mulla Khel the beds pitch southwards beneath younger strata. Over a large part of the Khasor range, the stage is overlapped by Tertiary (Siwalik) beds, but reappears southwest of Bilot beneath the Siwalik unconformity and, if Wynne's figure is correct, attains a maximum thickness of about 1,500 feet in the Shekh Budin area of the Khasor range.

In the trans-Indus Maidan range, the Baroch limestones are well developed north of Kalabagh and in the complicated Kutch area. At Chichali they have thickened to about 300 feet and, in the Baroch gorge at Mulla Khel, exhibit a fine section of 685 feet, forming part of the undisturbed western limb of the anticline occupying the range; in the latter area there is a gradual passage upwards of the Variegated beds into the Baroch stage, the basal beds of which include an appreciable proportion of shale and sandstone. In the Khasor range the Baroch limestones are apparently overlapped by the Tertiaries (Siwaliks) except perhaps to the east of Paniala; in the hills of Shekh Budin they are said to be from 800 to 1,000 feet thick.

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[1] L. F. Spath. *Pal. Ind.*, New Ser. XXV, Mem. 1,124 (1939).

[2] R. R. Simpson. *Rec.* XXXI, 17 (1904).

With regard to fossils, Wynne mentions the occurrence of *Belemnites* and Ammonites, *Pleurotomaria. Mytilus, Pecten, Myacites, Nerinaea, Cerithium, Rhynchonella, Corbula, Natica, Terebratula, Pholadomya, Ostraea, Goniomya*, crinoids, corals and *Echinus* spines, but no Trigoniae. Some grey clays at Paniala yielded impressions somewhat resembling the pinnules of *Ptilophyllum*. Cephalopoda appear to be more plentiful in the fine section exposed in the Chichali Pass. A specimen of *Belemnopsis gerardi* (Oppel) from Kalabagh is said to have been associated with numerous fragments of planulate ammonites and half a whorl of a cast resembling a *Macrocephalus* form. There appears to be no doubt that *gerardi*-like forms, possibly identical with Futterer's *Belemnopsis tanganensis*, occur, together with *Mayaites* and other Argovian ammonites, according to Dr. Spath who also records from Kalabagh *Subkossmatia flemingi* Spath, an ammonite which, though not found in Cutch, indicates a zone equivalent to that of the Anceps beds.[1] Some unlabelled fossils which, there seems little doubt, come from the Chichali Pass, have been identified by Dr. Spath as *Indocephalites* aff. *transitorius* Spath, *Indocephalites* sp., four *Pleurocephalites habyensis* Spath and allies, and one *Kamptokephalites* cf. *magnumbilicatus* (Waag.,) indistinguishable from examples from Jumara in Cutch. These specimens occur in the yellow and crimson matrix so characteristic of the ferruginous *Macrocephalus* beds of Cutch, a resemblance which at first caused them to be mistaken for Cutch fossils. From the Chichali Pass also Dr. Spath has recently recognised *Virgatosphinctes broilii* Uhlig, and a species which appears to belong to a Callovian *Putealiceras*[2] derived probably from the Baroch Limestone. From Makarwal—and probably from this limestone come *Hubertoceras* spp., *Obtusicostites* sp. and *Kinkeliniceras* sp., forms which are definitely Upper Callovian.[3] The same limestone north of Cutch has yielded *Hibolite pistilliformis*.

Some fossils collected near Shekh Budin belong, according to Mr. Tipper, to a Liassic fauna comparable in every respect with that so well developed in Baluchistan; they include two species of *Harpoceras*, *Pecten* sp., *Lima* sp., *Thracia* and others, specifically identical with Baluchistan forms.[4] The presence here of the Lias has been recently confirmed by the discovery of a species of *Bouleiceras* of the group *B. nitescens* Thev., characteristics of the very base of the Upper Lias.[5] From the Baroch Limestone at Shekh Budin come two brachiopods very closely related to the *Burmirhynchia* of the Namyau beds of Burma, and indicating probably a Callovian age; these have been named by Dr. M. R. Sahni: *Rhynchonella* (*Daghanirhynchia*) *coulsoni* and *R.* (*D.*) *pezuensis*. In this exposure the limestone is overlain by yellowish green glauconitic sandstone, of which the lower 500 feet contain large, imperfectly preserved belemnites while the upper part has yielded terebratulids below and ammonites and belemnites above. The brachiopods which indicate an Oxfordian-Kimeridgian age, have been determined by M. R. Sahni as follows[1] :—

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[1] *Pal. Ind.*, New Ser., Vol. IX., Mem. 2, 802 (1933).

[2] *Pal. Ind.*, New Ser., XXV, Mem. 1, 131 (1939).

[3] *Ibid.*, (121).

[4] *Rec.*, XLII 68 (1912).

[5] *Gen. Rep. Rec.* 72, 74 (1937).

Brachiopoda—
Zeilleria (*Ornithella*) *coulsoni* Sahni,
,, ,, *depressa* Sahni,
,, ,, *indica* Sahni,
,, ,, *paralagenalis* Sahni,
,, ,, *ovalis* Sahni.
Kingena punjabica Sahni,
'*Terebratula*' *bannuensis* Sahni,
Rhynchonella (*Daghanirhynchia*) *pezvensis* Sahni.

If the Shekh Budin outcrop is an undisturbed stratigraphical succession, the glauconitic sandstones overlying the Baroch Limestone cannot be the same as and must not be confused with the Cretaceous sequence which succeeds the Baroch stage elsewhere, but represents higher horizons of the Jurassic not present in other sections.

Reviewing the Jurassic of the Salt Range and its trans-Indus extension as a whole, we find definite evidence of the presence of the lower part of the Chari series (Middle and Upper Macrocephalus Beds and the Anceps stage which has been equated with the top of the Bathonian *plus* the Callovian and possibly of the Lias ; in addition there is an Oxfordian-Kimmeridgian horizon at Shekh Budin, and a Tithonian at Sokan. Several ammonites found in the overlying Cretaceous beds Valanginian and Infra-Valanginian) appear to have been derived from the Spiti Shales, and Dr. Spath concludes that the lower beds of the Spiti Shales were once continuous from the Himalaya, through Hazara and Attock, into Waziristan and Baluchistan, the facies being identical throughout.[2]

BALUCHISTAN.

Position and Distribution.—Fifty or sixty miles southwest of the Shekh Budin area of the Northwest Frontier Province, a large outcrop of rocks believed to be of Jurassic age encloses the Takht-i-Sulaiman (11,295 ft.), a mountain lying within the borders of Afghanistan. To the south of Fort Sandeman, other isolated outcrops make their appearance from beneath the mantle of Cretaceous which covers most of Zhob and much of Loralai. The strike of these several outcrops swings round with the hill ranges to the Quetta-Pishin syntaxis, whence a broad belt of more or less interrupted Jurassic exposures stretches southwards down the eastern portion of Kalat State (Sarawan, Jhalawan and Las Bela divisions) to within 45 miles of Karachi ; the southern end of this belt is some 165 miles northwest of the nearest Jurassic exposures in Cutch. East of Kalat both Jurassic and Cretaceous exposures are largely concealed beneath a vast plateau of Eocene limestone.

The eastern parts of Baluchistan are characterised by a great sequence of limestones belonging to several successive geological formations of which the Jurassic is one. To their competence is largely due the fact that the rocks here have not suffered the sharp flexuring of the western "flysch region" but have risen in large dome-shaped bulges often several miles across.[3] These limestone rocks range from Carboniferous to Pliocene, the Jurassic being particularly massive, dominating the physiography of the area and building up the most massive of the mountains. In the majority of cases the Jurassic rocks make their appearance as inliers in the Cretaceous. Around each roughly elliptic exposure of Jurassic, there is typically a ring of less lofty but steep ridges made up of regularly bedded Cretaceous limestones whose aggregate thickness is always much less than that of the older formation ; the clear white or red colour of these concentric younger beds contrasts noticeably with the dark tinge of the central Jurassic. Occasionally the structure is more disturbed. The well known mountain of Takatu near Quetta, for instance, one of a main line of peaks with a scarped face to the southeast and a northwesterly dip slope, is composed of massive Jurassic limestone which has been thrust southeastwards over the Cretaceous rocks of the lower ranges.[1] Along the synclinal valleys which normally intervene between the lines of domes the main channels of drainage have established themselves, and the whole region exhibits that marked parallelism between topographical features and geological strike, and that coincidence of hills with anticlines on the one hand and of valleys with synclines on the other, which are such typical characteristics of a region with a scanty rainfall—in the present case ranging from five to ten inches annually.

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[1] *Pal. Ind.*, New Ser., Vol. XXVII, Mem. 1 (1939).
[2] *Pal. Ind.*, New Ser., XXV, Mem. 1, 131 (1939).
[3] E. Vredenburg. *Rec.* XXXVIII, 190-1 (1909).

In the Kaliphat, a high range to the north of Shahrig rising 10,000 feet and upwards above sea level, there can be seen a more or less complete section comprising massive Jurassic limestone below, followed by the Cretaceous and capped by Nummulitic limestone. Three thousand feet of Jurassic strata are exposed in the Pil range, west of Ziarat. In the Wat Pass over the high range which separates the Luni plain from Zhob territory there are quite 2,000 feet, but the base is not exposed here.[2] Elsewhere the Jurassic sequence is spoken of as consisting of thousands of feet of limestone. In nearly all cases the base of the Jurassic is not exposed; in parts of the country between the town of Kalat and Khwaja Amran in the west of the Quetta-Pishin district, however, the Jurassic massive limestone rests with a marked unconformity upon dark shales which were at first thought to be the Kojak Shales (Oilgocene) but which are more probably of Triassic age (see page 902).[3]

Subdivision and Relationships.—The Jurrassic of Baluchistan consists of two portions, a younger, of Middle Jurassic age, made up of dark grey, extremely thick-bedded limestones, and an older, Liassic in age, which is of a still darker grey, almost black, with less massive layers, and very distinctly bedded. The Chehiltan hills and the Koh-i-Maran in Sarawan are built up of the former while the older beds have produced the hills of Anjira and Sumbaji and in Jhalawan. The Cretaceous limestones rest sometimes on the Middle Jurassic, sometimes on the Lias. This unconformity and that which is seen higher up, in the middle of the Cretaceous system, account for variations in the geological sections at different places and bear witness, not only to irregular denudation during the continental periods, but also to the fact that the subsequent encroachment of the sea was not simultaneous over the whole area. In this way formations represented by thousands of feet in one section may be feebly developed or completely absent at no great distance away, conditions which Vredenburg evidently regarded as not to any considerable extent the result of folding and thrusting.

The principal exposures of the Lias in Sarawan are to be found in the underscarp of the Chehiltau range, in the ranges enclosing the Manguchar and Shirinab valley both to the east and west, and in the Siah range west of Kalat. In Jhalawan the huge anticlinal domes consist mostly of Liassic beds. The principal ones are the eastern spurs of the Mulki and Palki, the southern continuation of these ranges forming the lofty hills of Belau, Hazar Meshi, Chilak, and other unnamed masses rising in the angle between the upper and lower Mula valleys, the enormous anticlinal domes of Zardak and Sumbaji to the southwest of Karu, several massive domes south of Zahri, the unnamed domes southwest of Khozdar and north of

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[1] *Gen. Rep.* 17 (1902-1903).

[2] *Rec.* XXVIII, 118 (1895).

[3] *Rec.* XXX, (1897).

Zidi, and the tall massive ranges east of the Porali. The last mentioned ranges continue into Las Bela territory east of the plain of Las Bela.

The Lias is described by Vredenburg as consisting of dark grey, almost black, regularly stratified limestones, several thousand feet thick sometimes interbedded with dark, richly fossiliferous, calcareous shales.

The division into Lower, Middle and Upper Lias, suggested by a study of the deposits in the field, have been fully borne out by an examination of the fossils; most of these come from the States of Kalat and Las Bela, but some were collected from the vicinity of Takatu. The Lower and Upper divisions are but poorly developed, while the Middle Lias includes almost all the exposures examined in Sarawan, Jhalawan and Las Bela.

The Lower Lias occurs in the form of crinoidal limestones and shaly beds in the Shirinab valley, south of Mastung, in Sarawan. The presence of an ammonite allied to the European *Arietites bisulcatus* Brug. proves the presence of the lowermost zone of the sub-division. Other fossils are by no means well preserved, and their affinities cannot be made out with satisfaction.[1] Incidentally the Lower Lias has been identified in the Persian Makran.

The Middle Lias includes the black limestones of Takatu, oolitic limestone and shales of Sarawan and northern Jhalawan, and black shales and limestones of southern Jhalawan and Las Bela, three areas which show some faunistic differences perhaps more apparent than real. In the rich and interesting fauna of the Middle Lias, ammonites are unfortunately very rare, and exact correlation is a matter of difficulty.

According to Mr. Tipper the Takatu area has yielded a fauna rich in number but poor in species. Among the collections of brachiopods are several specimens of *Spiriferina rostrata* Schloth., nearly a thousand specimens of a new species of the same genus, showing considerable variation in character, several specimens of the European *Rhynchonella tetrahedra* Sow., examples of *Terebratula synophrys* Uhlig., and its two varieties *pacheia* Uhl., and *polyptycha* del Piaz., and in considerable numbers a species of *Eudesia*, a genus not usually found below the Inferior Oolite. Of the lamellibranchs the commonest genus is that of *Pecten*, including a species related to *Pecten* (*Aequipecten*) *aequivalvis* Sow., and another to *Pecten* (*Entolium*) *hehlii* d'Orb.

Of the rich and varied Middle Liassic fauna of the Sarawan and northern Jhalawan area a full report is not available. No ammonites have been discovered. *Eudesia* is represented by a species different from that of the Takatu area, and *Pecten* by a very peculiar spiny species, somewhat resembling the South American Liassic *P. alatus* v. Buch, and so striking in appearance that it is worn as a charm by the inhabitants of Jhalawan. *Spiriferina distefanoi* del Piaz., found in this locality is a species with a high triangular area and peculiar ornamentation and probably deserves a subgeneric rank. The occurrence of a new genus of echinoids is also of interest.

The Porali river area in southern Jhalawan and Las Bela is particularly interesting, not only on account of the excellent preservation and number of the fossils, but also because many of them resemble closely Middle Liassic fossils from Madagascar. The Malagassy forms, *Pecten ambongoensis* Thev., *Spiriferina rostrata*, var., *madagascariensis* Thev., and the rare and peculiar ammonite genus

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[1] *Rec.* XXVIII, 26 (1909).

Bouleiceras, can all be matched from the Porali river collection which has yielded a fauna very similar to the Domerian-Toarcian fauna of southern Europe, comprising[1]: *Bouleiceras nitescens* Thev., associated with species of *Phylloceras*, *Rhacophyllites*, *Lytoceras*, *Fuciniceras*, *Protogrammoceras*, *Polyplectus*, *Dactylioceras*, *Porpoceras*, and a species of a new genus, *Sphenarpites hawkinsi* Spath.[2] Dr. Spath remarks that, with the exception of an entirely new sphenodiscoid, also found with the above, the assemblage might have come from the Apennines or from Sicily. The lamellibranch related to *Pecten ambongoensis* belongs to the same class as, and is closely related to the *Pecten* mentioned above from the more northern area ; a distortion of the left valve is thought by Tipper to have been caused by fixation during part of the life of the animal. Other members of this assemblage are *Lima* cf. *punctata* Sow., *L.* (*Plagiostoma*) *gigantee* Sow., and *Pholadomya* cf. *idea* d'Orb.

The Upper Lias has been found in the black shales of the Natrani river and has yielded a rich though not very well preserved ammonite fauna, including the following typical Upper Liassic forms : *Harpoceras* cf. *serpentinum*, *Dactylioceras* cf. *annulatum*, *Hildoceras* sp., and *Oxynotoceras* sp. The only other fossil associated with the ammonites is a graceful, ribbed *Spiriferina*, which occurs in large numbers. These fossils were all collected from one gentle dip slope, so that the whole of the Upper Lias is here crowded into a thin band of shale.

Bajocian and Bathonian.—Of the higher Jurassic the youngest strata contain a Callovian fauna. Between them and the Lias come several thousand feet of massive, grey limestones which from their position, have been assumed by Vredenburg to represent the Bajocian and Bathonian. The principal exposures of these massive beds are in the Chehiltan range, the ranges east of the Mastung valley, the Koh-i-Maran, most of the hills bordering the Bolan district, some ranges west of Shekran, and some hills near Wad.

Callovian of Mazar Drik.—The beds with the Callovian fauna consist of alternations of rather thin-bedded limestones and shales,[3] and are exposed in the core of the ? Morad (Morau) anticline, north of the plain of Narmuk in Sarawan, and in the Sembar Pass, Sibi district. From the Mazar Drik anticline in the Marri hills comes the "Mazar Drik fauna", which, according to Noetling, includes the two European brachiopods, *Terebratula ventricosa* Ziet., and *Rhynchonella plicatella* Sow., as well as undetermined species of *Lima*, *Gervillia*, *Pholadomya* and *Pleurotomaria*. The ammonites, as revised by Dr. Spath, comprise : *Oppelia baluchistanensis* Spath, *Kheraiceras quenstedti* (Roem), *Dolikephalites praetransiens* Spath (an almost perfect homoeomorph of the Argovian *Epimayaites transiens*, a simulation responsible largely for a misinterpretation of the age of the beds), *D.* aff. *praetransiens*, *Macrocephalites* sp. juv. aff. *formosus* (Sow.) (the *M. opis.* (Sow.) of Noetling), *Indocephalites dubius* Spath, *I.* aff. *gibbosus* Spath,[4] *Macrocephalites madagascariensis* Lem. (a Malagassy form), *Dolikephalites perlamellosus* Spath, *Pleurocephalites* sp. (*habyensis* group) (one of the specimens named by Noetling *Macrocephalites grantanum* (Oppel)), *Choffatia balinensis* (Neum.) (a Cutch form), *C. baluchisanensis* (Noetl) (another Cutch form), *C.* aff. *balinensis* (Neum.), *C.* aff. *recuperoi*

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[1] L. F. Spath. *Ann. S. Afr. Mus.*, XII. pt. vii, No. 16, p. 272 (1921) ; also *Pal. Ind.*, New Ser., Vol. XXII, Mem. 3, 18 (1936).

[2] *Ann. Mag. Nat. Hist.*, Ser. X, Vol. XVII, 641 (1936).

[3] The so-called "Polyphemus beds."

[4] This is Noetling's "*Macrocephalites polyphemus* (Waag.)"

(Gemm.) and *Indosphinctes* aff. *errans* Spath. This fauna is believed to be a uniform fauna of *Macrocephalus* age, and closely allied to that of the corresponding beds in Cutch. Nearly all the Mazar Drik fossils are deformed by pressure. Noetling identified three species of *Nautilus*, of which two are *Nautilus* (*Paracenoceras*) *wandaensis* (Waag.) and *N.* (*Procymatoceras* ?) *intumescens* (Waag.) both of them Cutch forms ; the third, "*Nautilus giganteus*" d 'Orb. was also thought to be a Cutch form, but the Cutch specimens have been allotted to different species by Spath who remarks that the Baluchistan example appears to be close, to Dacque's *N. ennianus*.

Tithonian.—Fragments of *Virgatosphinctes denseplicatus* (Waag.) from the Windar river, opposite the Gash Pass in Las Bela State, Baluchistan, indicate the presence in that locality of the Tithonian or Lower Umia.[1] Ammonites and molluscs of Bajocian age have been collected by Tipper in eastern Persia.[2]

THE SULAIMAN RANGE.

The meridional Sulaiman range, forming the boundary between the northern end of Baluchistan (Zhob) and the southern branch of Waziristan, consists throughout many miles of its length, of two parallel ridges united by an intervening tableland. The highest point of the western ridge is Kaisarghar (11,325 feet), that of the eastern ridge the well known Takht-i-Sulaiman (11,100 feet). The range is traversed by the Zao, Toi, Lohara and other watercourses, in wild, and gloomy defiles or *dhanas* which are so narrow and precipitous that the sky is sometimes invisible from the bottom, the walls of rock rising shear for several thousand feet. The gorge of the Lohara or Draband immediately beneath the Kaisargarh peak, is the well known "Gut", and is the deepest and narrowest of these extraordinary waterways.

The axial portion of the range is occupied by rocks referred to the Jurassic system, exposed along the core of a large anticline. These are overlain by Cretaceous beds which, along the eastern side, are followed by successive belts of Nummulitic and Siwalik Tertiaries occupying the foot hills fronting the Indus plains.

The lowest beds exposed are seen only in the deep ravines and are reminiscent of the Spiti Shales of the Himalaya.[3] They consist of black or dark grey, crumbling shales, often nodular ; in the south opposite Dera Ghazi Khan, they are described as calcareous, in the north they are traversed by numerous veins of calcite. These beds form the core of the fold where, in the Takht-i-Sulaiman area, they are squeezed into a vertical position. They pass up into grey, even-textured, marly shales, with thin irregular beds of sandy or shaly limestone, sandstone and ferruginous shales. The sequence so far detailed constitutes the lower stage of Dr. Blanford, of which about 1,000 feet are exposed in the south without the base being visible.[4] The limestones of this section are described as abounding in indistinct fossils, especially in foraminifera, and the underlying shales have yielded two species of *Exogyra*, one or two of *Inoceramus* and a transversely ribbed ammonite-like cephalopod. The most characteristic fossil is an *Inoceramus*, the valves of which are often found together, though wide open, and are sometimes six inches across. The supposed resemblance of the two Exogyrae to Middle Cretaceous forms was partly responsible for the beds being assigned at first to that system. In the more northerly parts the lower stage was recognised on both sides of the anticline.

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[1] L. F. Spath. *Pal. Ind.*, New Ser., Vol. IX, Mem. 2, Pt. 4, 535 (1931).

[2] *Rec.* LIII, 58 (1921). *Pal. Ind.*, New Ser., Vol. XXII, Mem., 2, 1, and 3 (1936).

[3] Griesbach. *Rec.* XVII, 184 (1884).

[4] *Mem.* XX, 146 (1883).

Next, in apparently conformable succession, come the beds of Dr. Blanford's upper stage, which occupies a considerable proportion of the eastern slope of the Sulaiman range and has yielded no fossils. In the south these beds consist of about 1,500 feet of sandstones and grits made conspicuous by their hardness and, by their colour which is generally pale, not infrequently speckled with brown occasionally greenish or purplish ; these appear to be the highest Mesozoic rocks exposed in this portion of the range. In the northern section the shales and thin limestones described above pass up on both sides of the anticline into coarse brown sandstones and grits with ferruginous concretionary partings. These are succeeded by beds which gradually become fine-grained and even-bedded, consisting mostly of a light brown or speckled quartz sandstone with a calcareous bed occasionally intercalated ; towards the top the limestone beds become more frequent, are seen to contain corals, and have yielded a few fragments of strongly ribbed ammonites. Griesbach estimated the thickness of this stage in the Takht-i-Sulaiman area at not less than 800 to 1,000 feet. It should be stated that this sandstone and grit stage has many points of resemblance with the main sandstone formation of the Samana range from the top of which Albian fossils have been obtained ; this sandstone and grit stage and all the other presumed Mesozoic rocks of the Sulaiman area, both above it and below, were originally mapped as Cretaceous by Blanford, Griesbach and LaTouche, though the second observer expressed the opinion that the lowest beds of all might be Jurassic.

In the northern area the sandstone group is overlain, at any rate on the eastern side of the anticline, by 50 to 100 feet of yellowish brown earthy shales and clays which are of much economic importance in that they form the underground floor of the local and extremely scanty water supply. The position of this band also coincides with a decided change in lithology, for, above it comes a great thickness, not less than 4,000 feet in the Toi ravine and exceeding 5,000 feet in the Zao river, of an intensely hard, compact, massive and very homogeneous limestone with scarcely any bedding planes.[1] The lower portion of this limestone is almost black and emits a slightly fetid odour when struck ; in it are a few sections of corals and gastropods. Higher up it becomes lighter in colour and contains more corals. In the Toi it is seen dipping to the east at about 30° ; in the Zao river it is approximately vertical. Along the greater part of its eastern outcrop the limestone is overlain by belemnite shales of Cretaceous age ; northwards, however, the latter appear to be overlapped by Eocene shales. There is much in favour of the view that this massive limestone is the equivalent of the Middle Jurassic of the Quetta neighbourhood and elsewhere.

SOUTHERN WAZIRISTAN.

Across the Takhi Zam in Southern Waziristan and partly covered by the alluvial deposits of the Kaniguram plain, stretches a broad belt of rocks including a black limestone which, in the opinion of Dr. Muray Stuart, bears a distinct resemblance to the lower portions of the massive Jurassic limestone of the Sulaiman range 30 miles to the south. This formation, to which the name of the Janjal

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[1] La Touche. *Rec.* XXVI, 77 (1893) ; Griesbach. *Rec.* XVII, 185 (1884).

Plant series has been given, begins with a lower portion of unfossiliferous red shales and siliceous limestones, weathering into a succession of knife-edge ridges and all dipping at steep angles in a W.N.W. direction; their eastern boundary is a fault bringing the beds into contact with Neocomian strata. Above the lower comes the main portion of the series, in the form of dark blue shales and subordinate black or deep blue limestones, with occasional black, slaty, pencil shales. The limestones and blue shales are full of carbonaceous markings thought to be the impressions of sea-weed, none of which is determinable.[1] The higher portion of the series, as far as it has been followed, is more arenaceous; the brown sandstones and occasional quartzites, of which it is composed, have yielded no fossils, but their weathered surfaces show markings very similar to the so-called fucoid markings that occur on the Pab sandstones of Cretaceous age. The upper boundary of this series has not been inspected and there is considerable doubt as to its age. Whether it forms part of the Gondwana sequence cannot be known until recognisable plants have been found.

Dr. Coulson has found that a very large area in Southern Waziristan is covered by a series of limestones and shales representing the greater part of the Janjal Plant beds, which extend into Zhob. The upper part of this formation has been recognised near Mangora Sar and Bobalai, and also near Razani in North Waziristan. A massive limestone occupies Bobai hill, cropping out in the centre of an anticline and overlain by shales which may belong to the lower horizons of the Janjal Plant series, is probably the equivalent of the Middle Jurassic limestone in the Takht-i-Sulaiman to the south and the Shekh Budin limestone (Baroch Limestone) to the north; the same limestone is seen east of Miram Shah forming the Zer Ghar. Both these limestones are more bituminous than that at Shekh Budin.

The Spiti Shales (Tithonian; see p. 1170) are well developed at Dargai Oba where though phyllitic, they are less disturbed than they are near Ladha; in the latter locality they have yielded a species of *Virgatosphinctes* of the group of *V. denseplicatus* Waag., a form typical of the Spiti Shales. West and south of Wana these shales are distinctly schistose throughout the greater part of the outcrop.[2]

TOCHI VALLEY.

Some 30 miles to the north of the last mentioned locality, in the Tochi valley of Northern Waziristan, the N.-S. anticlinal ridge between Idak and Miran Shah is composed of Lower Eocene rocks along the flanks and a thick core of massive, dark grey limestone, which may be the equivalent of the Middle Jurassic limestone of Baluchistan, but in which no fossils have so far been discovered.[3]

NORTHERN KOHAT.

Some 60 miles northeast of the last mentioned locality and 40 miles north of the Chichali (Maidan) range, the Jurassic is again exposed in the Samana range along the northern border of the Kohat district, half-way between the towns of Kohat and Thal, where it is the lowest formation seen at the core of an E.-W. anticline. Its beds can be divided into two portions, an older and a younger. The older is best seen at the extreme western end of the range, and is made up of reddish sandstones, with bands of shale and shaly limestone, containing sections of brachiopod shells, and, in places, remains of *Ostraea* ;[1] a small brachiopod from some pale greenish shales near the top has been identified by Miss Muir-Wood as *Rhynchonelloidea arcuata* (Quenst.), a form found at the base of the Callovian in Germany and similar to *Rhynchonella varians* Müll, which has been recognised, among other places, in the Bathonian or Callovian of Dar-es-Salam in East Africa. On this scanty evidence the older portion of the Samana Jurassic would appear to belong to the uppermost Bathonian or possibly early Callovian.

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[1] Murray Stuart. *Rec.* LIV, 90, (1922).

[2] *Gen. Rep. Rec.* 72, 24-25 (1937); 73, *Ibid.*, 84 (1938).

[3] *Rec.* XXVIII, 109 (1895).

Above these lower beds lies the younger portion, consisting of 400-500 feet of dark grey, almost black limestone, with traces of unextractable ammonites, belemnites of both hastate and lanceolate varieties, sections of large brachiopods, and many fragmentary crinoid remains among which *Pentacrinus* can be recognised.[2] This limestone, which occupies more or less the stratigraphical position of the Spiti Shales, is darker than younger limestones in the Samana succession, and is further distinguishable therefrom by its generally coarse, almost granular texture ; the organic remains are especially noticeable among its upper layers. It forms escarpments in the lower parts of the valleys eroded into the southern flanks of the range, and has produced the great precipitously-placed rock platform, known as the Samana Suk, at the western end of the range, which played such a prominent part in the battle of Dargai in 1897.

PESHAWAR DISTRICT.

Limestone, believed to be of Jurassic age, crops out near Mir Kalan and to the north of Jalala Sar in Peshawar.[3]

BARA VALLEY, TIRAH

South of the Safed Koh and its eastern continuation the Morga range, and between it and the Samana range, a belt of country, some 30 miles wide, made up of alternating E.-W. ranges and valleys, is occupied largely by Mesozoic rocks which have been thrown into inverted folds and crop out in steep scarps facing south and more or less gentle dip slopes in a northerly direction. The crumpling and disturbance, as well as the lack of fossils make the establishment of the geological sequence difficult. These Mesozoic rocks, comprising Trias, Jurassic and Cretaceous, occupy by far the greater part of the belt and are cut off from the older rocks to the north by the great fault mentioned previously (p. 901). From Hayden's text most of the rocks south of the band of Trias which adjoins the fault belong to the Cretaceous and, in fact, no Jurassic fossils seem to have been obtained. To the Rhætic formation, however, Hayden assigns a series of crushed red shales and overlying grey limestones which occupy the high range to the south of the narrow trough eroded by the Bara river out of the soft Triassic shales and grits.[4] These beds, well exposed in an arrow defile of the Bara river between Mir Khan and Dwatowi are overlain by the Triassic beds to the north, and brought into abrupt contact with younger Jurassic and Cretaceous rocks to the south ; like the latter they are bent into steep anticlines and synclines and locally faulted.

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[1] H. H. Hayden. *Mem.* XXVIII, 102 (1898).

[2] Col. L. M. Davies, *Pal. Ind.*, New Ser., Vol. XV, Pt. 1, pp. 5-6 (1930).

[3] *Rec.* 73, 84 (1938).

[4] *Mem.* XXVIII. 104-107 (1898).

The dark, grey massive limestone, not less than 2,000 feet thick, with its occasional narrow bands of carbonaceous shale, becomes somewhat arenaceous towards the base and passes gradually down into the red shales ; no recognisable fossils have been obtained from these beds.

SPITI, GARHWAL AND KUMAON.

Kioto Limestone.—The Jurassic rocks of the Himalaya have long been known by their fossils, which had acquired a sacred character and become objects of commerce. As we have seen, the homogeneous mass of grey limestones and dolomites known as Kioto Limestone, and sometimes referred to as the Megalodon Limestone, must include, not only the equivalents of the Noric and Rhætic Dachsteinkalk of the Eastern Alps, but also of the Lias and of the Lower and Middle Oolites. No Rhætic types appear to have been found in this section of the Himalaya, and the presence of this series is tentatively inferred merely from the uninterrupted sequence, with no trace of unconformity, seen in the largely inaccessible precipices of this limestone formation, in which occasional fossil levels occur. From one of these horizons, 800 feet above the base of the Limestone or top of the Middle Noric Quartzite, specimens of *Spiriferina* cf. *obtusa* Opp. have been collected between Giumal and Chabrang in Spiti, and probably indicate a Liassic age.[1] About 1,000 feet above this horizon, and some 370 feet below the top of the limestone, another fossil layer near Giumal has yielded an ammonite which was originally described as identical with or very nearly allied to *Stephanoceras coronatum* Brug., a Middle Oolite species ; Dr. Spath, however, believes the specimen to consist of the inner whorls of some macrocephalitid, such as *Kamptokephalites* (*dimerus* group) or *Pleurocephalites* (*habyensis* group), indicating a late Bathonian or early Callovian age.[2]

In Painkhanda, Johar and Byans the Kioto Limestone, although exhibiting occasional sections of some species of *Megalodon* even in its topmost layers, must be regarded as astride approximately the same geological limits as it is in Spiti. There is a decrease in thickness from about 2,300 feet in Spiti to 1,930 or 2,130 feet in Painkhanda, and thence to 1,600 feet in Byans.

Between Kungribingri and Laptal in northwest Kumaon Messrs. Heim and Gansser have recognised Liassic horizons ("Laptal series"), extending probably over Painkhanda into Spiti ; they are described as of shallow-water, marine type, some 60-80 metres thick and characterised by repeated layers of shell agglomerate including specimens of *Ostraea*, *Arca*, *Pecten*, *Lima*, *Astarte*, *Trigonia* and *Belemnites*.[3]

Beds between the Kioto Limestone and Spiti Shales, including the Sulcacutus Beds.—In the Shalshal section of Painkhanda the uppermost 130 feet or so of the Kioto formation consist of earthy, thin-bedded limestones and marls, which act as passage beds up into another well known sub-division, the Spiti Shales. Both in Spiti and Painkhanda these passage beds have yielded many fossils which do not appear to have been described. In the Shalshal cliff the following succession has been made out:

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[1] C. Diener. *Mem.* XXXVI, 302 (1912).

[2] *Pal. Ind.,* New Ser., Vol. IX, Mem. 2, Pt. 6, 804 (1927).

[3] *Denkschr. d. Schweiz. Naturf. Gesells.*, Bd. LXXIII, 209 (1939).

Spiti Shales—		
6. Sulcacutus beds	6	feet
5. Yellowish grey, earthy limestones and marls, with *Rhynchonella* sp.	4	,,
4. Thin-bedded, yellowish grey limestones, with *Belemnites* sp., *Ostraea* sp. and *Pecten* sp.	20	,,
3. Lithodendron limestone with crinoid stems	100	,,
2. Thin-bedded limestones with many Liassic bivalves	2 or 3	,,
1. Well bedded limestone	1,800—2,000	,,
	1,930—2,130 feet.	

Bed No. 2 is said to contain many bivalves with Liassic affinities, but no record of the fauna seems to have been published. The ferruginous oolites and pisolites of the Sulcacutus beds, so named after their most characteristic fossil, *Belemnites (Discoelites) sulcacutus* (F. E. Suess), occurring at the base of the Spiti Shales, constitute a very constant horizon of Callovian age in the Himalayan Mesozoic from Spiti to Byans. From these beds are recorded species of *Macrocephalites*, *Sphaeroceras* (*S. dieneri* Suess), *Kepplerites* and *Rhynchonella* sp. (*lacunosa* group, Quenst.)[1] but the type specimens seem to have been lost,[2] the presence of *Kepplerites* in the opinion of Dr. Spath requires confirmation. The best exposures of these pisolites are to be observed on the western slope of Chanambaniali in Almora.[3]

From a ferruginous limestone at Laptal, Heim and Gansser have collected the following Callovian species as determined by A. Jeannet[4]:—

Belemnoidea—

?*Belemnites* (*Belemnopsis*) *calloviensis* Oppel.

Ammonoidea—

Macrocephalites cf. *triangularis* Spath (Lower Callovian),
Macrocephalites (*Dolichocephalites*) cf. *flexuosus* Spath (Lower Callovian of New Guinea),
Reineckeites aff. *waageni* Till. ("Anceps zone"),
Reineckeites douvilléi Steinm. ("Anceps zone"),
Bonarellia cf. *bicostata* Stahl. ("Athleta zone"),

Brachiopoda—

Rhynchonella sp.

Spiti Shales.—In the Spiti, Garhwal and Kumaon Himalaya the steep limestone cliffs of the Zanskar range, built up of the Kioto formation, are usually capped by undulating downs covered with black, friable shales which have yielded large numbers of ammonites and belemnites of Upper Jurassic type. These Spiti Shales, as they are called, succeed the Sulcacutus beds with every appearance of conformity inspite of the complete lithological change, and, in their characteristic facies, extend at least from Hazara in the west to the Everest region and Sikkim in the east. In the type area of Spiti they cap the cliffs on the left side of the Spiti river near Kibber, Langja and Giumal; they also occur along the higher ridges on the right side of the same river, and form a narrow strip above Mani, extending over the saddle of the Manirang Pass into Bashahr.[5] From the adjoining Tibetan Province of Ngari Khorsum the beds cross into Garhwal and Kumaon as a narrow outcrop which, between the Shalshal and Chitichun Passes, splits into two. In this part of the Himalaya the Spiti Shales are frequently seen to be squeezed into the narrowest folds and in places have been overthrust by the rigid Cretaceous strata. Disturbed sections of this nature can be seen in the Dharma and Lissar valleys where all that remain of the Shales are very narrow strips enclosed in crushed folds of the Kioto limestones.[1] In the majority of cases, however, the Spiti Shales, whether they form a continuous or fragmentary sequence, occupy a well defined stratigraphical position between the Kioto or Megalodon Limestone formation below and the greenish Giumal sandstones above. The upper boundary is less sharply defined than the lower and the passage into the shaly, greenish sandstones of the Giumals more gradual than the change from the underlying earthy limestones into the Spiti Shales.

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[1] C. Diener, *Denks. k. Akad. Wiss. Wien.* LXII, p. 584 (1895).
[2] L. F. Spath. *Pal. Ind.*, New Ser., vol. IX, Mem. 2, 805 (1927).
[3] C. Diener, *Mem.* XXVIII, 2 (1898).
[4] *Denkschr. d. Schweiz, Naturf. Gesells*, Bd. LXXIII, 142 (1939).
[5] H. H. Hayden, *Mem.* XXXVI, 85 (1904).

Very constant in lithological character, the Spiti series everywhere consists of dark grey and black shales, containing numerous calcareous concretions, a large proportion of which being formed round fossils. The thickness of these Shales in Spiti is about 500 feet.[2] The original extent of their exposure has been very much reduced by the great denudation they have undergone.

The Spiti Shales have been divided into the following three sub-divisions :

1. Lochambel stage.
2. Chidamu stage.
3. Belemnite Shales.

but certain discrepancies between the faunas of the different stages arouse the suspicion that the few hundred feet of Spiti Shales exposed at the various localities are not astride exactly the same horizons, and that most of the individual successions are incomplete.[3] It is possible, therefore, that more precise collecting will show that there has been a certain amount of admixture or overlapping with regard to the lists of fossils given below.

The lowest stage consists of brown earthy shales at the base, with traces of *Belemnites* and other fossils, surmounted by black, splintery, friable shales, occassionally micaceous, and with rust-coloured, ferruginous blotches on their fractured surfaces ; in the latter nodules of iron pyrites are common, and scattered throughout are calcareous concretions in each of which is usually a poorly preserved fossil. Amongst the few fossils identified from this stage are : *Belemnopsis gerardi* Opp. (ranging up into the middle stage, and recorded also from Kalabagh, Cutch and the Dutch East Indies ; Oxfordian) ; *B. alfuricus* Bohm (also found in the Salt Range and in the Oxfordian of the Dutch East Indies) ; *Mayaites* ("*Macrocephalites*") *waageni* (Uhl.) Spath ;(4) *M.* ("*Macrocephalites*") *kitchini* (Uhl.) Spath (comparable with the young *Kamptokephalites lamellosus* (Sow.) ;(4) *Epimayaites* sp. (the "*Macrocephalites* cf. *maya*" of Uhlig)(4) ; *Grayiceras* (?*Prograyiceras*) ("*Simbirskites*") *koeneni* (Uhl.) ;(5) *Prograyiceras grayi* Spath ("*Stephanoceras*

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[1] C. L. Griesbach, *Mem.* XXIII, 77, (1891).

[2] Griesbach records a thickness of 1,350 feet to the north of the Niti Pass, but this may be exaggerated by disturbance *Mem.* XXIII, 126, (1928).

[3] L. F. Spath, *Pal. Ind.* New Ser., Vol. XX, Mem. 4, 34 (1934).

[4] From what stage of the Spiti Shales these three ammonites come has not been definitely stated, but there seems little doubt that they were collected from the lowest stage (see *Mem.*V, 95).

[5] *G. koeneni* is not a near relative, as was at one time supposed, of "*Simbriskites fissus*".

(*Simbirskites*) *nepalense*" Waag. (Gray); *Inoceramus* cf. *sularum* G. Böhm; *I.* sp.; *Lima melancholica* Holdh.; *L. tristicula* Holdh.; *Cerithium*? sp. (small).[1]

The ammonites and the coarsely ribbed Inocerami indicate an Upper Oxfordian or Argovian age, and the stage shows affinities more especially with the Upper Oxfordian of Wai Galo in the Dutch East Indies.

The middle or Chidamu stage is similar in lithological character to the upper part of the lower, and consists of fine, black, splintery shales, with many ferruginous partings and marly concretions which generally yield well preserved fossils, especially ammonites. From this level the great majority of Spiti Shale fossils have been derived, though information concerning their precise horizon is wanting in a large number of cases. The following is a list of forms which, on the authority of Professor Uhlig, have been collected from the Chidamu stage, most of them at Chidamu locality:

Belmnoidea—
Belemnopsis gerardi (Opp.) (from Chojan as well as Chidamu).

Phylloceratidae—
Phylloceras plicatius Uhl. (from the Shalshal cliff only).

Lytoceratidae—
Lytoceras exoticum Opp.

Oppelidae—
K. *Hecticoceras latistrigatum* Uhl.,
U..T. *Streblites kraffti* Uhl.,
,, *griesbachi* Uhl. (from Shalshal as well as Chidamu).,
,, *punctatopictus* Uhl.,
,, *domocrenatus* Uhl.

Eucycloceratidae—
Kossmastia desmidoptycha Uhl. (from Lochambel-ki-chak only).

Hoplitidae—
Blanfordia wallichs Gray. (from Chojan).

Perisphinctidae—
Paraboliceras sabineanum Opp.,
,, *tibeticum* Uhl.,
,, cf. *spitiense* Uhl.,
L.T. *Virgatosphinctes denseplicatus* Waag. (Shalshal and Chojan as well as Chidamu, also in the Umia beds of Cutch).,
,, *raja* Uhl.,
,, *rotundidoma* Uhl.,
,, *intermedius* Uhl.,
L.T. ,, *frequens* Opp.,
.T. ,, *subfrequens* Uhl. ,
,, *himalayanus* Uhl. (from Shalshal as well as Chidamu).,
,, *kraffti* Uhl.,
,, *kutianus* Uhl. (from Shalshal).,
,, *contiguus* Zitt. (from Shalshal only; also found in the Kimmeridgian and Tithonian of Europe).,
,, *discoides* Uhl.,

Perisphinctes (*Aulacosphinctes*) *tibetanus* Uhl. (Chojan as well as Chidamu).,
,, ,, *parvulus* Uhl. (Shalshal).,
,, ,, *torquatus* Sow.,
,, ,, *radialecostatus* Steig.,
,, ,, aff. *hollandi* Uhl.,
,, *dieneri* Steig.

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[1] *Denkschr. K. Akad. Wiss. Wien. Math.-Nat.* Kl., Vol. LXXXV, 558; L. F. Spath, *Pal. Ind.*, New Ser., Vol. IX, Mem. 2, Pt. 6, 804-5 (1927).

Brachiopoda—

Rhynchonella aff. *lacunosa* Steig, (Shalshal, Jandu, Niti and Ting Jung La)

Lamellibranchiata—

Pseudomonotis inornata Holdh.
  ,, *amoena* Holdh.
Aucella spitiensis Holdh., and varieties.
Inoceramus everesti Opp. (from Shalshal as well as Chidamu ; also found in the Katrol beds of Cutch).
  ,, *stoliczkai* Holdh. (from Shalshal only).

K. typically Kimmeridgian.
LT. Lower Tithonian.
UT. Upper Tithonian.

In both numbers and species the brachiopods play a very subordinate part in the Chidamu fauna ; all the groups are universally distributed ones and the fact that the nearest allies are found in the Upper Jurassic of Middle Europe and the Mediterranean is to some extent accidental and due to the detail in which the latter fauna has been studied. The bivalves do little more than confirm the evidence of the ammonites, though a few of them point generally to an Upper Jurassic age.[1] The ammonite fauna of the Chidamu beds is uppermost Kimmeridgian-Portlandian in age. Between it and the Argovian or Upper oxfordian mayaitid fauna of the Belemnite Shales there is a considerable palæontological break. The absence of such genera as *Waagenia* and of distinctive oppelids and perisphinctids, as well as the great scarcity of aspidoceratids, indicates a time gap covering the Corallian, and the Lower and Middle Kimmeridgian.

The upper or Lochambel stage is found at Lochambel-ki-chak, two miles or so east of the peak of Chitichun No. 1 ; very probably it also occurs at Kuti in Byans and in parts of Ngari Khorsum, judging from the number of Lochambel species recorded from these localities. The bulk of the stage belongs to the Upper Tithonian but, judging from the evidence of its *Hoplites*—such as *H.* (*Kilianella pexiptychus* Uhl., *H.* (*Neocomites*) *neocomiensis* d'Orb., *H.* (*Thurmannia*) *thurmanni* —and of its *Acanthodiscus subradiatus* and *Simbirskites* aff. *discofalcatus* Lah., it ranges up into the Neocomian,[2] probably to the base of the Hauterivian. The Lochambel beds too are made up of dark, splintery shales but with fewer concretions and, near the top, frequently alternating with more regularly bedded black shales and impure limestones ; towards the upper part of the stage also thin intercalated beds of light-coloured sandstone make their appearance, introducing the superjacent Giumal sandstones up into which the beds pass. In this stage ammonites become scarcer, and belemnites and bivalves predominate.[3] This stage in Uhlig's opinion, is made up of the Berriasian (Infra-Valanginian) and the Valanginian ; equating the Lower Berriasian with the Tithonian, this sequence corresponds to the Tithonian and Valanginian, *i.e.*, the highest Jurassic and lowest Cretaceous series. The following is his list : [4]—

Morphoceratidae—

Holcostephanus (*Spiticeras*) *spitienesis* Blanf.
  ,, ,, *subbilobatus* Uhl. & Suess.
  ,, ,, *binodiger* U. & S.
  ,, ,, *conservans* U. & S.
  ,, ,, *subcautleyi* U. & S.
  ,, ,, *mojsvari* U. & S.

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[1] Carl Holdhans. *Pal. Ind.*, Ser. XV., Vol. IV, 398 (1910).
[2] A. Spitz. *Rec.* XLIV, 212 (1914).
[3] C. L. Griesbach. *Mem.* XXIII, 77 (1891).
[4] *Denksch. K. Akad. Wiss. Wien. Math. Nat. Kl. vol. LXXXV.*

Holcostephanus (*Spiticeras*) *scriptus* Strach.
,, ,, *griesbachi* U. & S.
,, ,, *guttatus* Strach.
,, ,, *eximius* U. & S.
,, (*Astieria*) *schenki* Opp.
,, ,, cf. *convoluta* Koen.
Himalayitidae—
Himalayites seideli Opp.
,, *ventricosus* Uhl.
Perisphinctidae—
Perisphinctes (*Paraboliceras*) *jubar* Blanf.
,, ,, *sabineanus* Opp.
Hoplitidae—
U. T. *Berriasella* cf. *privasensis* Pict.
U. T. *Hoplites* (*Blanfordiceras*) *wallichi* Gray.
,, *cricki* Uhl.
,, *applanata* Uhl.
,, *böhmi* Uhl.
,, *latidoma* Uhl.
,, *middlemissi* Uhl.
,, *celebrant* Uhl.
Acanthodiscus octagonoides Uhl.
,, *polyacanthus* Uhl.
,, *subradiatus* Uhl.
,, *acanthinus* Uhl.
,, *hookeri* Blanf.
,, *latouchei* Uhl.
,, *acanthoptychus* Uhl.
Acanthodiscus smithi Uhl.
,, aff. *hystricoides* Uhl.
,, *spitiensis* Uhl.
,, aff. *michaelis* Uhl.
,, *tibetanus* Uhl.
,, *asiaticus* Uhl.
,, *himalayanus* Uhl.
Kilianella pexiptycha Uhl.
,, *leptosoma* Uhl.
,, *constricta* Uhl.
Thurmannia boissieri Pict.
,, *kingi* Uhl.
,, aff. *rarefurcatus* Uhl.
Sarasinella varians Uhl.
,, *subspinosa* Uhl.
,, aff. *ambiguus* Uhl.
Neocomites cf. *neocomiensis* d'Orb.
,, *nivalis* Uhl.
,, *montanus* Uhl.
,, *indomontanus* Uhl.
,, *calliptychus* Uhl.
,, *pycnoptychus* Uhl.
,, *walkeri* Uhl.
,, *nikitini* Uhl.
,, *indicus* Uhl.
,, *odontodiscus* Uhl
Pleuromya spitiensis Holdh.
Avicula spitiensis Opp.

The following is list of additional forms whose position in the Spiti Shale series is unknown or uncertain but, in the great majority of cases, is in the Chidamu stage.[1]

Phylloceratidae—
UT. *Phylloceras strigile* Blanf.

Lytoceratidae—
Lytoceras exoticum Opp. (Laptel in Ngari Khorsum ; Tangtat, north of Kibber ; and Chidamu).

Oppelidae—
K. *Hecticoceras kobelli* Opp. (Shangra ; found also in the Middle Katrol sandstone of Cutch).
Oppelia (*Neumayria*) *nivalis* Stol. (Kibber).
,, (*Oecotraustes*) adela Uhl. (Base of the Spiti Shales, in Tera Gadh).
UT. ,, (*Streblites*) *adolphi* Opp. (Raj Hoti, in Ngavi Khorsum).
UT. ,, ,, *planopicta* Uhl. (Sirkia, southern Ngari Khorsum).
,, ,, *himalayana* Uhl. (Spiti).
,, ,, *indopicta* Uhl. (Jandu, in Ngari Khorsum).
,, ,, *substriata* Opp. (Shangra, in Ngari Khorsum).
,, ,, *lymani* Opp. (Giumal and Jandu).
,, ,, *sphenodoma* Uhl. (Kibber, in Spiti).
,, ,, *platydoma* Uhl. (Jandu and Spiti).
,, ,, *leptodoma* Uhl. (Giumal and Laptel.).
,, ,, *adunata* Uhl. (Jandu).
,, ,, *pygmaea* Uhl. (Giumal , and N. of Ting Jungta).
,, ,, *crassicostata* Uhl. (Ngari Khorsum).
,, *acucincta* Strach.

Aspidoceratidae—
Aspidoceras avellanoides Uhl. (Near Kibber ; rare).

Morphoceratidae—
Holcostephanus (*Spiticeras*) *grotei* Opp. (Spiti).
,, ,, *subspitiensis* Uhl. (Spiti).

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[1] V. Uhlig. *Pal. Ind.*, Ser. XV, Vol. IV (1910).

Holcostephanus (*Spiticeras*) *bilobatus* Uhl. (Kibber).
UT. ,, ,, *planus* Uhl. (Kibber).
,, ,, *cautleyi* Opp. (Laptel).
,, ,, *stanleyi* Opp. (Jandu and Laptel).
,, ,, *bulliformis* Uhl. (Spiti).
,, ,, *oppeli* Uhl. (Tibet).
,, ,, *obliquelobatus* Uhl. (Giumal).
,, ,, *indicus* Uhl. (Spiti).
,, ,, *speciosus* Uhl. (Kibber).
tobleri Uhl. (Ngari Khorsum).
Himalayites *kutianus* Uhl. (Kuti).
,, *schlagintweiti* Uhl. (Spiti).
,, *hollandi* Uhl. (Spiti).
,, *stoliczkai* Uhl. (Near Giumal).
,, *umbo* Strach. & Blanf. (Niti).
,, *hyphasis* Blanf. (Giumal).
,, *hoplitiformis* Uhl. (Spiti).

Hoplitidae—

Hoplites (*Blanfordiceras*[1]) *rotundidoma* Uhl. (Lingti river).
,, *subquadratus* Uhl. (Giumal).
,, ,, *curvatus* Uhl. (Chanambaniali).
,, ,, *acuticosta* Uhl. (Spiti).
,, (*Acanthodiscus*) *octagonus* Strach. (Kibber and Kuti, in Byans).
,, ,, *hundesianus* Uhl. (N. of Ting Jung La).
,, ,, *sommeringi* Opp. (Spiti and Kuti).
,, ,, *medea* Blanf. (Niti).
,, ,, *ruprechti* Opp. (Tengdi, Spiti).
,, (*Kilianella*) aff. *epimelloides* Par. (Ngari Khorsum).
,, (*Sarasinella?*) *cautleyi* Opp. (Shangra and Spiti).
,, (*Neocomites*) *theodori* Opp. (Laptel).
Kossmatia *tenuistriata* Gray. (Probably Niti).

Perisphinctidae—

Perisphinctes (*Grossouvria*) *propinquus* Uhl. (Chikkim).
,, (*Paraboliceras*) *rectecostatus* Uhl. (Locality unknown).
,, ,, *cyrtoptychus* Uhl. (Kuti).
,, ,, *himalayanus* Uhl. (Shangra and Jandu).
,, ,, *haugi* Uhl. (Sangcha and Kuti). (? Kuti Byans).
,, ,, *polysphinctus* Uhl. (Locality unknown).
,, ,, *mutilus* Opp. (Spiti).
Perisphinctes ,, *griesbachi* Uhl. (Jandu).
,, ,, *pompeckji* Uhl. (Kibber).
,, ,, *fascicostatus* Uhl. (Locality not stated).
,, (*Virgatosphinctes*) *minusculus* Uhl. (Spiti).
,, ,, *pompeckji* Uhl. (N. of Jandu).
,, ,, *holdhausi* Uhl. (Laptal).
,, ,, aff. *denseplicatus* Waag. (Spiti, Jandu and Chidamu).
,, ,, *burckhardti* Uhl. (Tongtak ? and Laptal).
,, ,, *multifasciatus* Uhl. (Jandu and Laptal).
,, ,, *haydeni* Uhl. (Jandu and Laptal).
,, ,, *broilii* Uhl. (Shangra, Laptal and Niti).
,, ,, *subquadratus* Uhl. (Spiti).
,, ,, *indistinctus* Uhl. (Laptal).
,, ,, *incertus* Uhl. (Between Ting Jung La and Chhota Hoti).
,, ,, *lemoinei* Uhl. (Shangra).
,, ,, aff. *euplocus* Waag. (Between Ting Jung La and Chhot Hoti).
,, (*Aulacosphinctes*) *morikeanus* Opp. (Ki in Spiti, Jandu, Giumal and Kuti).
,, ,, *spitiensis* Uhl. (Jandu, Giumal and near Chidamu).
,, ,, *rareplicatus* Uhl. (N. of Ting Jung La).
,, ,, *hollandi* Uhl. (Jandu).
,, ,, *natricoides* Uhl. (Chidamu and Shalshal).
,, ,, *latouchei* Uhl. (Chidamu).

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[1] Many of these *Blanfordiceras* may have come from Lochambel beds (See *Pal Ind.* New Ser., Vol. XX, No. 4, p. 33 (1934).

Perisphinctes (*Aulacosphinctes*) *pachygyrus* Uhl. (N. of Ting Jung La).
,, ,, *linoptychus* Uhl. (N. Kumaon, Sirkia and Shalshal).
,, ,, *mayeri* Uhl. (Shangra and Jandu).
,, ,, aff. *striolatus* Steuer (Jandu and Kuti).
,, ,, *kossmati* Uhl. (Kibber).
,, *divergens* Sterg (Shangra).
,, *perrin-smithi* Uhl. (Chidamu).
,, ,, *ophidoides* Uhl. (Chidamu).
,, ,, *shangraensis* Steig. (Shangra).[1]
LT. ,, ,, *pseudocolubrinus* W. Kilian. (Shangra, Laptal, Chidamu Sirkia and Chhota Hoti in Ngari Khorsum).
,, ,, aff. *lorioli* Zitt. (Shangra).
,, ,, *subtorquatus* Uhl. (Laptal and Shangra).
,, ,, *infundibulum* Uhl. (Chidamu, Jandu, between Ting Jung La and Chhota Hoti, and Spiti.)
,, ,, *smith-woodwardi* Uhl. (Spiti, Puling in Ngari Khorsum, ? Chidamu).
,, ,, *willisi* Uhl. (Between Ting Jung La and Chhota Hoti, Laptal and Giumal).
,, ,, *hundesianus* Uhl. (Chidamu, between Chidamu and Laptal, and N. of Ting Jung La).
,, ,, cf. *adelus* Gemm. (Chidamu and Laptal).
,, ,, *chidamensis* Uhl. (Chidamu and Shangra).
,, ,, *sparsicosta* Uhl. (Chidamu).
,, *biplicatus* Uhl. (Kibber, Sirkia in south Ngari Khorsum, west of Chikkim, and Shangra).
,, *dacquei* Steig (Shangra)
,, *alternecostatus* Steig (Locality unrecorded).
Bochianites gerardianus Stol. (Locality unknown).
Rhynchonella aff. *sparsicosta* Quenst (Niti).
,, aff. *hoheneggeri* Suess. (Jandu).
,, aff. *moeschi* Haas. (Kibber).
,, cf. *astieriana* D'Orb. (Locality unrecorded).
Terebratula sp.
Aucella leguminosa Stol. (Kibber).
,, *blanfordiana* Stol. (Jandu, Kibber, Sirkia and Niti).
Inoceramus gracilis Holdh. (Niti).
Lima roberti Opp. (Locality not given).
,, *spitiensis* Holdh. (Kuling and Kibber).
Pecten inertulus Holdh. (N. of Kibber).
Nucula spitiensis Holdh. (Kibber, Chikkim and Ginmal.)
,, *hycmorpha* Holdh. (Chikkim and ?).
,, *kibberiana* Holdh. (Kibber).
,, *dieneri* Holdh. (Giumal).
Leda sp. (Between Chidamu and the Kisangur Pass.)
Arca (*Parallelodon*) *egertoniana* Stol. (Giumal, Kibber and "Spit.")[2]
Trigonia spitiensis Holdh. (Giumal).
Astarte hermanni Opp. (Chikkim and ?)
,, *sowerbyana* Holdh. (Kibber, Chikkim and ?)
,, *scytalis* Holdh. (Locality not given).
,, *spitiensis* Holdh. (Locality unrecorded).
Cosmomya egregia Holdh. (Niti).
Homomyo tibetica Stol. (Giumal).
Goniomya whiligi Holdh. (Niti).
Pholadomya ? *problematica* (Between Chhota Hoti and Ting Jung La).
Pleurotomaria spitiensis Holdh. (Kibber, Giumal and ?).
K. typically Kimmeridgian.
LT. Lower Tithonian.
UT. Upper Tithonian.

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[1] Thought by Dr. Steiger to be identical with what Waagen calls *P. bleicheri* from the Umia beds of Cutch ; the Cutch specimen has been renamed *Aulacosphinctoides meridionalis* by Dr. Spath who considers that it differs in most characters from *P. shangraensis* and is not identical with de Loriol's *P. bleicheri*.

[2] "*Macrodon egertoniana*" Stol., *Cucullaea egertoniana* Stol. found in the Aden hinterland. G. H. Tipper. [*Rec.* XXXVIII, 336 (1910) and in Kenya *Geol. Mag.*, LXIV, 325 (1927).]

In spite of purely numerical anomalies, the Jurassics of Cutch and of the Himalaya are intimately related and would be demonstrably more so were it not that the most fossiliferous portions of each sequence are probably not quite at the same stratigraphical levels. The affinity with the Spiti Shales is especially distinct in the Umia beds of Cutch with its *Virgatosphinctes* fauna. The differences in the ammonite faunas of the two areas, which were at one time regarded as those of facies, are now attributed to slight differences in age. In Uhlig's opinion, the Spiti Shales are neither littoral nor thalassic sediments but are lithologically very similar to the Dogger of the Caucasus and to the Wernsdorf and Upper Teschen beds of Silesia.[1] They denote a northward recession of the Tethys sea, and represent the muds which were brought down by rivers from the south and succeeded the open sea limestones of the Kioto period. As will be seen, this recession ended ultimately in the northern ranges of the Himalaya and the whole of Tibet becoming a continental area in Tertiary times. The Spiti Shales fauna shows a close connection with Cutch and East Africa on the one hand and with central Europe on the other ; the boreal element is entirely absent.

NEPAL.

From the Salagrammi, the Nepalese name for the upper Gandak river, a small collection of fossils made in all probability by Dr. N. W. Wallich near Mukhtinath north of the Nepalese crystalline peaks, have proved to be nearly all closely related to forms in the Spiti Shales of Kumaon and Garhwal.[2] Dr. Cowper Reed, to whom this discovery is due, has determined the following : *Belemnites* (*Discoelites*) cf. *sulcatus* Mill., *Hoplites wallichi* Gray, *Perisphinctes* cf. *biplex* Sow., *P.* cf. *torquatus* Sow., *P.* aff. *frequens* Opp., *P.* cf. *sabineanus* Opp., *Oppelia* (*Streblites*) cf. *griesbachi* Uhl., *Parallelodon egertonianus* Stol. (found in the Aden hinterland), *Nucula* sp. and *Rhynchonella* cf. *variabilis* Schloth. Incidentally the discovery clears up the derivation of the word " *saligram* ", applied to rounded black stones regarded as sacred by Hindus. Some of these are the concretionary bodies with nuclei of ammonites, such as are so typical of the Spiti Shales ; many of the so-called *saligrams* obtainable in Indian bazars are black, rounded pebbles of various kinds of rocks, and presumably, therefore, business instincts have given rise to a wider application of the name, the outward and visible features being not always accompanied by the internal structure that is supposed to be essentially connected with the sacred character of the stone.

EXOTIC BLOCKS OF MALLA JOHAR.

Of the exotic blocks of Malla Johar, in the upper Kiogarh valley of Ngari Khorsum, No. 8, as numbered by von Krafft, and others, consist of a light grey, massive, dolomitic limestone. No trace of a fossil has been found therein, but they have the appearance of being portions of the Kioto Limestone of Dachsteinkalk age, through the lithological identity between the two is not beyond question. Messrs. Heim and Gansser find that the so-called exotics of Kiogarh are not simple blocks, but part of a folded sedimentary series of vast extent which is less broken up by basic intrusions; these authorities note that part of von Krafft's basic igneous rocks are nothing but folded Jurassic sediments.[1]

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[1] C. Diener. *Mem.* XXVIII, 20 (1898.)

[2] *Rec.* XXXVII, 136 (1908), and F. R. C. Reed. *Geol. Mag.* 256 (1908).

Among the blocks the Lias is represented by Nos. 4, 6, 7, 16 and 17, which are composed of a very earthy, brick-red, rather thin-bedded, nodular limestone, with a few thick grey layers. No fossils have been found in No. 4. Blocks 6 and 7 have yielded : *Phylloceras* cf. *sclateri* Dien., *P.* aff. *montgomeryi* Dien., *Aegoceras* sp., *Arietites* aff. *grunowi* v. Hauer and *Belemnites* sp.; *Belemnites* and ill-preserved bivalves are common in certain of the earthy layers of Block 6. The fauna of these is of Lower Liassic age. Of the same age is the more copious assemblage from Nos. 16 and 17.[2]

Cephalopoda—

Atractites sp.
Phylloceras *montgomeryi* Dien.
,, *sclateri* Dien.
,, *horsefieldi* Dien.
,, *caldwelli* Dien.
,, aff. *dieneri* Rosenb.
,, (*Schistophylloceras*) *mongolicum* Dien.
Rhachophyllites cf. (*gigas*) Fuc.
,, *schofariformis* Dien.
Analytoceras aff. *articulatum* Sow.
Pleuracanthites aff. *biformis* Sow.
Ectocentrites sp.
Oxynoticeras aff. *greenoughi* Sow.
Schlotheimia aff. *trapezoidalis* (Sow). Can.
,, aff. *marmorea* Opp.
Aegoceras sp.
Arietites cf. *coregonensis* (Sow.) San.
,, *himalayanus* Dien.
,, *rotiformis* Sow.

Of the number of fossils collected by von Krafft nearly 60 per cent. consists of specimens of *Phylloceras*, a predominance which imparts an Alpine aspect to the fauna; this resemblance is supported by the affinities of individual species as well as by the lithological character of the rock.

Several of the exotic blocks rest upon the Spiti Shales, and some of them are composed of the shale. The difference in facies between the normal Himalayan formations and those represented by the exotic blocks strewn along the Tibetan border is greater in the case of the Lias than it is in the case of the Trias.

TIBET.

Distribution and General Character.—By far the most striking feature of the geology of southern Tibet is the enormous tract occupied by Jurassic rocks which are exposed with little interruption over an area of many thousands of square miles from the northern flanks of the Himalaya northwards across the Tsang-po and beyond Lhasa. This great outcrop, with its monotonous topography, is in all probability more or less continuous through Nepal with that of Kumaon, Garhwal, Spiti and Ngari Khorsum. In these eastern parts of the Himalayan region the general lithological characters of the system resemble those in the west except that, whereas in the latter region the lower portion, up to the Oxfordian is entirely calcareous, in the east it is only partially so, sandstone and shale being the predominant types even in the more basal sections[1]; in both regions the upper beds are wholly free from limestone. Along their contast with the granite of the crystalline zone to the south the lower beds are not only metamorphosed but considerably disturbed ; in fact the crystalline zone itself includes schistose and gneissose rocks of Jurassic age through which the less altered slates and shales appear to pass into the foliated granite. The junction of the less altered types with the crystalline zone is, however, in most cases obscured by talus or moraine.

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[1] *Denkschr. d. Schwer Natarf. Gesells.*, Bed. LXXIII, Abh. 1, 145 (1939).
[2] C. Diener. *Pal. Ind.*, Ser. XV, Vol. I., Pt. 1, 94 (1908).

Mount Everest Region.—To the north of the crystalline belt which encloses Mount Everest the southern boundary of the less altered Jurassics is situated about two miles north of Rongbuk village ; these rocks cover the greater part of the Pharuk district and occupy the bulk of the Ladakh range immediately to the north. They consist for the most part of dark brown and black shales and argillaceous sandstones with subordinate quartzites and limestones ; the quartzites represent a purer form of sandstone, but the limestones are usually darker and more argillaceous than those of the overlying Cretaceous system.[2]

In the country between the crystalline zone and the Ladakh range, the Jurassic strata were found by Dr. Heron to be thrown into great folds and fantastically corrugated, the general strike of the folds, omitting frequent irregularities, being that of the " grain " of the country, *viz.*, E.-W. or E.S.E.-W.N.W. Thrust-faulting is most probably very prevalent, but extremely difficult to detect in such uniform strata. In the Ladakh range some injection by granite has caused a widespread regional induration of the rocks. In the latter the degree of metamorphism is low. The shales for the most part have acquired the beginning of slaty structure; they have become knotted and break into prisms, or have developed a certain amount of secondary sericitic mica and aluminous silicates such as staurolite. In places they have become phyllities. A baked appearance is common, the whitish or red colour contrasting with the black or rusty brown tints of the unindurated shales. The quartzites show no more alteration than do those found among the unaltered strata. That the crystalline schists of this neighbourhood include representatives of the Spiti Shales is proved by the specimen of *Uhligites griesbachi* (Uhlig), a typical Spiti Shale fossil, recorded by Mr. N. E. Odell from the Phut La at the head of the Rongshar Chu, a valley carved out of the crystallines to the west of Gaurisankar (Chomo Tsering, 18,940 ft.). In a watercourse leading up from Dra to the Ruli La were collected also three fragments of early macrocephalitids including *Dolikephalites subcompressus* Waag. and *Pleurocephalites* sp. From beds mapped (erroneously) as Kampa (Cretaceous) at Tingri Dzong Mr. Odell brought back a fragment of a *Kamptokephalites* of the *dimerus* group, found by Dr. Spath to be indistinguishable from a species occurring at the base of the upper Middle Macrocephalus beds of the Jumara area in Cutch.[3]

Tsang and U.—Further to the east a similar belt of metamorphosed Jurassic flanks the northern slopes of the granite mass which includes Chomoyumo (23,400 ft.) and Pauhunri (23,180 ft.) peaks. It occupies a comparatively low range of hills separated from the granite moraines to the south by the Lachen river which here runs approximately from east to west. Over these hills run the passe which lead from the broad open Lachen valley into Tibet. The rocks consist of red and black slates, sandstones, quartzites and conglomerates, more or less altered by the neighbouring granite, for the most part unfossiliferous, and dipping northwards. A block of quartzite thought to have been derived from one of the eastern spurs of Chomoymo was seen to contain crinoid stems and yielded some poorly preserved brachiopod casts including a species of *Rhynchonella* resembling *R. quadriplicata* Ziet. East of the descent from one of the passes the Sibu-La—to Giri, a small group of hills is composed of typical shales, dark in colour, with many bands of concretions containing fragmentary ammonites; above the Spiti Shales, on the left bank of the Giri river, are contorted limestones belonging presumably to the Cretaceous system. North of this the Giri valley coincides with an important E.-W. line of faulting which brings up on the north side of the river Jurassic quartzites and slates overlain by Spiti Shales, which continue northwards almost to the Kampa ridge.[1] The crinoid limestone seen at the Tso Lhamo, at the head of the Lachen valley, is thought to be the same as the Jurassic limestone seen in the Phari plain some miles to the southeast; in addition to the crinoid stems, small fragmentary lamellibranchs and bryozoa were observed in the rock, one of the former belonging possibly to the genus *Trigonia*.

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[1] H. H. Hayden. *Mem.* XXXVI, 146 (1907).

[2] A. M. Heron. *Rec.* LIV, 229 (1922).

[3] A. Von. Kraft. *Mem.* XXXII, 147 (1902).

Near Lungma, a summer grazing ground some eight miles south of Kampa Dzong, a 50-foot band of highly fossiliferous limestone furnished a definite horizon in the Jurassic system. The well preserved fossils indicate a Lower Oolite age and include:

Cephalopoda—

- *Harpoceras* (*Dorsetensia*) cf. *complanatum* Buckm.
- ,, spp. (several species).
- *Stephanoceras* cf. *humphresianum* Sow.
- *Nautilus* sp.
- *Belemnites* sp.

Brachiopoda—

- *Rhynchonella quadriplicata* Ziet.
- ,, *variabilis* Schloth.
- ,, spp.
- *Terebratula* cf. *ventricosa* Ziet.

Lamellibranchiata—

- *Trigonia costata* Park.
- ,, sp.
- *Pecten* sp.
- *Pholadomya* sp.
- ? *Lima pectiniformis* Schloth.
- *Ostraea* sp.
- *Pleuromya* (*Myacites*) cf. *adjectus* Phill.

The lower beds are characterised by lamellibranchs in large numbers, *Trigonia costata* being especially noticeable. Brachiopods are apparently absent from the lower beds, but especially characteristic of the middle, while the cephalopods are confined to the highest beds. The slates and shales overlying the limestone also contain traces of fossils.

The lower slates exposed on the ridge at the foot of the ascent to the Naku La contain a few traces of fossils, including a small *Pecten*.

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[1] H. B. Hayden. *Mem* XXXVI, 152-153 (1907).

In the Phari plain, southwest of Chomolhari (23,930 ft.), the Dothak series which has already been described under the heading of Trias and may itself possibly include Jurassic horizons, is succeeded by some thin-bedded limestones yielding a number of small brachiopods belonging to either Liassic or Rhætic species and comprising a *Waldheimia* identical or closely allied to *W. resupinata* Sow., and species of *Rhynchonella*, *Spiriferina* and *Spirigera*. Some coral limestones of the neighbourhood are believed to occupy an intervening position between this brachiopod limestone and the next higher member of the Jurassic sequence, which consists of slate and quartzite ; one of these crushed slates has yielded the impression of an ammonite. Crinoid limestones, thought to overlie the slate and quartzite, contain numerous traces of indeterminable bivalves and brachiopods, but have been crushed and disturbed by off-shoots of the Pauhuri granite mass. Finally come the shaly beds on which the Fort of Phari stands.

Part of the range from the Tremo La to Chomolhari is probably composed of Jurassic rocks.

Hayden suggests the following correlation of the Tibetan Jurassics so far considered as a working hypothesis :

	Lachen, Kampa-dzong area.	Phari area.
Upper Jurassic	Spiti Shales	?
Upper and Middle Jurassic.	Black and grey shale and quartzite.	Shale and quartzite.
Middle Jurassic	Lungma limestone	Upper limestone.
Lias(? and Rhætic)	Slate, quartzite and conglomerate. Tso Lhamo crinoid limestone.	Slate and quartzite. Crinoid limestone. Slate and quartzite. Brachiopod limestone.

With the exception of a belt of Cretaceous north of the Phari plain and two or three narrow outcrops of the same rocks near Lhasa, omitting also a small boss of granite south of Gyantse and two or three outcrops of the same rock around Lhasa, the whole of the area intervening between that capital city and Phari, a distance of some 175 miles, appears to be covered by slate, quartzite (rarely shale and sandstone) and limestone, thrown into an endless succession of complicated folds and pierced by dykes of basic igneous rock and intrusive masses of granite. Most of the fossils have been destroyed by the intrusions, but from their lithological character the rocks are all referred to the Jurassic system. At the village of Gorchi, in the valley of the Ralung Chu, large numbers of *Belemnites* were collected from a band of soft shales. At various other widely spread localities the following few fossils have also been recorded : *Gryphaea* sp., *Spiriferina* sp., impressions of a brachiopod externally resembling *Terebratula* (*Megerla*) *perrieri* Desl., *Rhynchonella* sp., *Perisphinctes* sp. and possibly other ammonites crinoids and " fucoid " remains.

Ngari Khorsum.—In Ngari Khorsum or Hundes, the equivalent of the Spiti Shales has been recognised by Heim and Gansser near Raksar, one of the Manasarowar Lakes.

Central Tibet.—The untimely death of Sir Henry Hayden has deprived us of detailed, though disappointing, as admitted by him, information concerning his extensive traverses from Lhasa westwards and northwards to Wom-po and Lhumpo. In 1907, however, he noted that in the immediate neighbourhood of Lhasa granite is the prevailing rock and the local sedimentary beds are highly metamorphosed, but Jurassic rocks still predominate in the surrounding hills and appear to continue far to the north towards Nam Tso.[1] A specimen from a belt of folded calcareous rocks Near Se-shing, some 30 odd miles northwest of Lhasa, proved to be a ferruginous oolite.[1]

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[1] *Mem.* XXXVI, 161 (1907).

KASHMIR.

Punch Jurassics.—In the Pir Panjal of Kashmir, and round the syntaxis between that State and Hazara, the Giumal Sandstone and the Spiti Shale horizons (Argovian to Gault) are thought to be both represented by a persistent band, 100-150 feet thick, of a vivid orange colour, infolded into the white contorted Eocene limestones.

Tagling Limestone.—The various ocurrences in Kashmir of the Kioto or Megalodon limestone, which probably includes Rhætic and Liassic horizons and is elsewhere seen at the base of the Spiti Shales, have already been described. To the upper part of this limestone Stoliczka gave the name of Tagling Limestone and it is this which is probably of Lower Jurassic age.

Karakoram area.—The Filippi expedition to the Karakoram brought back an interesting collection of Jurassic fossils from the so-called " Ammonite valley " and from other neighbouring localities in the basin of the Shyok immediately south of the Karakoram Pass. The rock in which the fossils occur is an impure, compact, more or less marly limestone. Usually it is of a fragile nature due to the system of minute calcite-filled fissures which traverses it ; when sound, it is a hard resistant rock, sombre-grey in colour, more or less suffused with red. The red streaks and spots are due to the presence of earthy hæmatite in microscopic globules which in places are seen to be concentrated into small masses with irregular but perfectly defined outlines. There is evidence to show that the hæmatite has been derived from glauconite and that the irregularly shaped masses in which it often occurs are the remains of organic bodies.

The microscope also reveals the presence of spicules of tetractinellid sponges and foraminifera ; amongst the latter are *Rotalia*, *Cristellaria*, *Truncatulina*, *Textularia*, *Lagena*, Miliolids, *Orbulina* and *Globigerina*. The state of preservation of the larger fossils is more or less deficient, most of them being fragmentary or deformed. The fauna is made up of 16 cephalopods—for the most part Stephanoceratidae and Harpoceratidae—11 lamellibranchs—two of them new species, and the families Pectinidae and Limidae specially represented—and 3 brachiopods of the genera *Terebratula* and *Rhynchonella*, two of them new species. In numbers the cephalopods greatly predominate, all the other forms with the exception of *Pecten* aff. *textorius*, being more or less rare.[3]

CEPHALOPODA[4]—

Stephanoceratidae—

Reineckeia reissi Steinm.	This is the *Perisphinctes anceps* of the Anceps beds in Cutch, and the *Olcostephanus straussi* Weith. of northwest Persia.
,, *greppini* Opp.	Known in the Callovian of Europe, Madagascar, Persia and Bolivia.
Perisphinctes furcula Neum.	Known in the Callovian of Europe and perhaps identical with *Choffatia* aff. *furcula* (Neum.) from Cutch.
,, *recuperoi* Gemm.	From the Callovian of Europe, the Jurassic of Baluchistan, and probably found also in Bolivia, also a Cutch form.

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[1] A. L. Coulson. *Rec.* LXVII, 331 (1933).

[2] N. E. Odell. *Geogr. Journ.*, LXVI, 301 (1925) ; Spath. *Pal. Ind.* Ser-, Vol. IX, Mem. 2, 806 (1927).

[3] G. Stefanini Spedizione italiana de Filippi nell Himalaia, Caracarume, Turchestan cinese. *Ser.* II, Vol. VI, 6 (1913-14).

[4] From the list have been omitted *Cosmoceras* sp. and *Perisphinctes* (*Villanya*) *densiloba tus*-Till, since the preservation of the specimens is so poor as to make determination doubtful (see L. F. Spath *Pal. Ind.*, New Ser. Vol. IX, Mem. 2, 806 (1927)).

Perisphinctes (*Grossouvria*) cf. *berthae* Liss. A French form.
,, ,, *tenellus* Teiss. From the Callovian of Europe.
,, ,, *balinensis* Neum. Identical with or very close to *Choffatia balinensis* from Cutch ; found also in Europe, Persia, Baluchistan and Madagascar.
,, (*Procerites*) *funatus* Opp. A European Callovian form ; not identical with Waagen's *P. funatus* which has been renamed by Spath *Sivajiceras aureum*.
,, ,, *moorei* (Opp. ?) Neum. Upper Bathonian of Europe.
,, ,, *baranyaensis* Loczy. From the Callovian of Hungary.
,, sp. Dr. Spath is inclined to take this to be a worn Spiti Shale *Aulacosphinctoides*.

Harpoceratidae—

Ludwigia pavlowi (Tsyt.) From the Callovian of Europe. Spath is prepared to admit the identity of this with his Cutch form *Lunuloceras orientale*.
Hecticoceras metomphalum Bon. Found in Europe and in Persia.
Oppelia calloviensis Par. & Bon. From the lower Callovian of Europe.

Lamellibranchiata—

Pecten aff. *textorius* Schl. *textorius* is a Liassic species.
,, (*Chlamys*) aff. *inaequicostatus* Phill. A European form.
,, ,, aff. *fibrosus* (Sow.)
Lima subcardiiformis Grepp. ?From the Bajocian probably up to the Lower Oxfordian of Europe.
Ctenostreon aff. *luciense* d'Orb. From the Great Oolite of France and England.
Avicula (*Oxytoma*) cf. *scarburgensis* Roll. From the Bathonian of England and France.
Pholadomya bucardium Agass. Bathonian or Lower Callovian of England and Switzerland.
Goniomya dacquei Stef. Identical with a Callovian form from Dar-es-salam, Kenya Colony.

Brachiopoda—

Terebratula dainellii Stef.
Rhynchonella de fillippii Stef. cf. *R. edwardsi* (Chap. & Dew. ?) Douv.

Sr. Stefanini correlates this Karakoram fauna with the lower part of the Chari in Cutch, with the Mazar Drik fauna of Baluchistan, and with the ferruginous pisolite immediately underlying the Spiti Shales of the Himalaya, *i.e.*, with the Callovian of Europe. The same authority concludes that the Karakoram limestones must have been accumulated in a sea rather open than deep. The fauna is entirely wanting in boreal elements, and belongs clearly to that of middle Europe and the Mediterranean.

From the Remo (Rimu) valley on the north flank of the Karakoram have been collected :[1]

Cephalopoda—

Reineckeia reissi Steinm.,
Perisphinctes furcula Neum.,
,, *gleimi* Steinm.,
Tylostoma sp.
Pecten (group) *textorius* Schl.,
,, (*Chlamys*) sp.

The Spiti Shales have been traced as far as the northern limit of the Karakoram range. Jurassic fossils have been found by Auden in the South Aghil range, to the north of the Karakoram, occupying a tectonic basin 16 miles long[2].

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[1] *Atti. d. R. Accad. d. Sci. d. Torino*, LXVII, 179 (1932).
[2] Gen. Rep. *Rec.* LXXIII, 91 (1938) ; *Him. Journ.*, X, 43 (1938).

Bajocian (Lower Dogger).—

- Brachiopoda—
  - *Terebratula perovalis* Sow.,
- Lamellibranchiata—
  - *Pecten (Entolium) gingensis* Quenst.,
  - ,, *(Camptonectes) lens* Sow.,
  - ,, ,, cf. *aratus* Waag.,
  - ,, *(Variamusium) pumilus* (Lam.), var. *subpersonata* (Vacek),
  - *Alectryonia* aff. *semisolitaria* (Etalon).
  - *Gervillia* (?) aff. *ferruginea* Benecksc,
- Gastropoda—
  - *Natica* sp.
  - *Pleurotomaria* sp.

Bajocian-Bathonian.—

- *Pecten (Camptonectes)* cf. *lens* Sow.,
- ,, *(Entolium)* cf. *demissus* Phillips.

Bathonian (Middle Dogger).—

- Echinoidea—
  - *Clypeus boblayei* Michelin.
- Brachiopoda—
  - *Terebratula dainellii* Stefanini,
  - *Burmirhynchia guttula* Buckman,
- Lamellibranchiata—
  - *Ceromya concentrica* Sow.,
  - *Modiola* cf. *plicata* Sow.,
  - *Isocardia nitida* Phillips,
- Cephalopoda—
  - *Parkinsonia* cf. *compressa* (Quenstedt),
  - *Perisphinctes (Zigzagiceras) arbustigerum* (d'Orb.)
  - *(Procerites)* aff. *moorei* (Oppel).
  - *Carantia* cf. *bathonica* Lissajous.

Callovian (Upper Dogger).—

- Brachiopoda—
  - *Terebratula* sp.
  - "*Rhynchonella*" cf. *nobilis* (Sow.),
  - ,, aff. *varians* Schloth.,
  - *Aulacothyris alveolata* Rollier.
- Lamellibranchiata—
  - *Chlamys fibrosa* (Sow.),
  - *Alectryonia* aff. *semisolitaria* (Etalon),
  - *Ctenostreon proboscideum* Sow.,
  - *Spondylopecten* cf. *bouchardi* (Oppel),
  - *Pholadomya carinata* Goldfuss, var.,
  - *Ceromya* sp.,
- Cephalopoda—
  - *Reineckeia douvillei* Steinmann,
  - ,, cf. *gaillardi* Roman,
  - ,, cf. *oxyoptycha* (Neumayr),
  - *Choffatia recuperoi* (Gemm.),
  - ,, cf. *furcula* (Neumayr),
  - ,, cf. *gottschei* (Steinmann),
  - *Indosphinctes patina* (Neumayr),
  - ,, cf. *choffati* Parona & Bonarelli,
  - *Grossouvria* cf. *variabilis* (Lahusen),
  - *Hecticoceras punctatum* Stahl,
  - *Oppelia* cf. *calloviensis* Parona & Bonarelli,
  - *Belemnites* sp.,

From the Dogger or Malm come: *Gresslya* sp., *Pholadomya* sp., *Nerinea* sp., and *Perisphinctes* sp. The Argovian or Lower Malm of this region has yielded: *Lithacoceras* cf. *virgulatus* Quenst. and *P.* aff. *polyplocus* Reinecke, while from the Tithonian or Upper Malm has been collected *Virgatosphinctes denseplicatus*

(Waag.). An *Astrocoenia* and an *Aspidoceras* have been found in beds which may be of Malm age, while *Hoplites* (*Berriasella*) sp., comes from strata which may be of Tithonian or Valanginian (Lower Cretaceous) age.

Kashmir District.—In the wide synclines near Baltal on the upper Sind river, E. N. E. of Srinagar, the Upper Trias passes upwards into a series of contorted, dark, pyritous slates, with thin limestones containing indeterminable remains of ammonites and of rod-like bodies which may be *Belemnites*; these beds may represent either the Lias or the Lower Oolite[1].

HAZARA.

On the other side of the Jhelum, the Spiti Shales in Hazara, wherever their base is exposed, rest upon the Kioto limestone, though in certain parts of the district a slight stratigraphical break appears to intervene.[2] Not only is the lithological change abrupt from a hard compact limestone to friable shale, but in a few sections, including one near Tanakki, the surface of the underlying limestone is seen to have been eroded, over-stepped by the basal ferruginous layer of the shales, and bored by molluscs.

The Spiti Shales, surmounted by the Giumal Sandstone are present in both the Slate and Nummulitic zones. About 200 feet thick in the northerly parts they decrease southwards and southwestwards to a few feet of black shale passing up through black shaly sandstone into Giumal Sandstone with *Trigonia*, and eventually die out altogether. In the small temple-crowned hill near Hassan Abdal still further southwest and within the Attock district, both Spiti Shales and Giumal Sandstone are absent and the Nummulitics rest directly upon Kioto Limestone.

When best developed, in the more northerly exposures, the bottom bed of the Spiti Shales is a layer of crystalline martite, some six inches thick, more or less changed to earthy brown haematite and limonite. Above this come the normal jet-black or soot-black shales, very fissile though only slightly micaceous, and often with shining lamination surfaces. Through them run lines of ferruginous, and slightly sandy concretions parallel to the bedding. These concretions, ranging up to a foot in diameter, vary in shape from a flattened ovoid to an irregular subangular mass and, unlike those of Spiti and Kumaon, possess no fossil nuclei; when split open they show red, black and yellow concentric coats.

Fossils from the Spiti shales of Hazara include: *Belemnopsis gerardi* Opp., *Oppelia acucincta* Strach., *Perisphinctes* (*Virgatosphinctes*) *frequens* Opp., *Inoceramus* sp., *Cucullaea* sp., *Pecten* sp., and *Corbula* sp., the localities being Changla Gali (Chumbi peak), Mount Sirban and the Darwaza-Kas near Dunga Gali.

Karakoram area.—The Aghil range, a northeastern adjunct of the Karakoram, has yielded to the recent Dutch expeditions of 1922, 1925, 1929-30 and 1935 evidence of the presence of several stages of the Jurassic. From below upwards the following faunas have been identified:

Octagoniceras—closely related to *O. octagonoides* Uhl. and to *O. subradiatus* Uhl.[3]—from the Murree-Abbottabad road, 16 miles from Murree; *Pseudo*

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[1] Gen. Rep. *Rec.* 72, 77-78 (1937).

[2] C. S. Middlemiss. *Mem.* XXVI, 29 (1896).

[3] This belongs to an horizon higher than that which yielded the Tithonian, *Virgatosphinctes frequens* (*Pal. Ind.*, New Ser. IX, Mem. 2, 804 (1933)).

monotis sp., *Aucella spitiensis* Holdh., *Inoceramus* sp., and several casts of *Cardium* sp. from Kalapani on the Thandiani road[1]. From what is described as the Giumal Sandstone, overlying the Spiti Shales near Kuthwal, H. C. Das Gupta records *Arca* cf. *egertoniana* Stol., *Corbula middlemissi* Das-Gupta, and *Perisphinctes* (*Virgatosphinctes*) *frequens* Opp.; the ammonite, which is abundant at the locality, is a Lower Spiti Shale form, and its presence would seem to indicate that horizon[2].

ATTOCK.

Whether the red, ferruginous beds seen in the Kioto Limestone at several localities in the Attock district of the Punjab represent or not the Sulcacutus beds of the Himalaya, or whether the equivalent of the latter is seen in the laterite layer which sometimes forms the uppermost bed of the Kioto Limestone, is not yet known.[3]

In the Kala Chitta Hills it is difficult to separate the beds corresponding to the Spiti Shales from those which represent the Giumal Sandstone. That both stratigraphical horizons are present is shown by the fossils, but the two form a single condensed band not exceeding 320 feet in thickness and usually less ; in most cases the beds are sheared and attenuated and occur typically as isosynclinally or isoanticlinally squeezed bands in the Kioto Limestone or the Nummulitic Limestone respectively. In two sections, however, one northwest of the village of Bata and the other on the hill slopes north of Ghora Mar., Mr. Lahiri has found it possible to differentiate the equivalent of the Spiti Shales from the Giumals the former in the first section consisting of 160 feet of soft, sandy and carbonaceous shales, and in the second of 200 feet of soft, shaly, carbonaceous belemnite beds associated with yellow and olive clays.

The Kioto Limestone of this region which, as already stated, includes a fossiliferrous horizon belonging to the Upper Trias, has yielded two other very meagre faunas, one of Liassic age and another, still younger, belonging probably to the Bajocian. The Liassic assemblage, preserved in a rubbly grey limestone, comes from a locality a short distance west of Garhiala, in the western Kala Chitta, and includes such characteristic forms as *Lima* (*Plagiostoma*) *gigantea* Sow. and *Pecten* (*Velata*) *velatus* Goldf ; in addition *Plicatula spinosa* (Schloth.). The younger fauna, also preserved in a grey rubbly limestone, was collected from a section east of Burjianwala, Laman, and comprise : *Eomiodon indicus* Cox, *Protocardia grandidieri* (Newt.), *Corbula lyrata* Sow., all of which occur abundantly in the basal Jurassic of Cutch at Kuar Bet, probably in the Lower Pachham stage. At any rate they occur below Pachham beds containing Bathonian ammonites. The Burjianwala fauna, therefore, which is post-Liassic, must be either Bajocian or Bathonian in age ; from their undoubted correspondence to certain beds in Madagascar containing two out of the three forms mentioned above and generally referred to the Bajocian., Mr. L. R. Cox assigns the Indian beds provisionally to the latter.[4]

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[1] *Pal. Ind.*, New Ser., Vol. IX, Mem. 2, 804 (1933).

[2] *J. A. S. B.*, New. Ser., Vol. XI, p. 253-257 (1915).

[3] G. da. P. Cotter. *Mem.* LV, 80 (1933).

[4] *Pal. Ind.*, New Ser., Vol. XX, Mem. 5, p. 2 (1935).

This horizon also appears to be present in the Garhiala locality and has yielded two brachiopods identified by Miss Muir-Wood as *Sphaeroidothyris attockensis* Muir-Wood and *S. indica* Muir-Wood[1].

At the southern end of the first tunnel between Campbellpur and Jalar, Miss Muir-Wood has established the presence of a younger horizon which may represent the Cornbrash or Callovian and is evidently close to the Namyau horizon of Burma ; from it come the brachiopods : *Burmirhynchia* cf. *namyauensis* Buckm., *B.* cf. *parva* Buckm., *B.* cf. *turgida* Buckm., and *Daghanirhynchia ?* cf. *daghaniensis* Muir-Wood (a genus found in British and Italian Somaliland, probably also in other parts of Africa, in Madagascar and in Bokhara). This same horizon appears to be present also near Garhiala and has furnished a species of *Kablirhynchia*.

From what are the equivalents of the Spiti Shales the following Argovian ammonites and belemnites have been collected from several localities including the vicinities of Burjianwala Laman, Talidhok, Bagh Nilab, and Bata :

AMMONOIDEA—

Epimayaites polyphemus (Waag.).
  ,, aff. *lemoinei* Spath.
Perisphinctes orientalis Siem.
  ,, *jelskii* Siem.
  ,, cf. *indogermanus* Waag.

Dichotomosphinctes cf. *orbignyi* (P. de Lor.).
  ,, aff. *grossouvrei* (Siem.).
  ,, ? aff. *waehneri* (Siem.).
Biplices aff. *de-riazi* (Siem).
  ,, aff. *subrota* (Choff.).
Pachyplanulites pralairei (Favre).
Prososphinctes virguloides (Waag.).

BELEMNOIDEA—

Hibolites budhaicus (Stol.).
  ,, cf. *windhouveri* Stolley
  ,, cf. *tibeticus* (Stol.).
  ,, cf. *planohastatus* (Roehm.).
  ,, (*Hastites*?) cf. *claviger* (Waag.).
Belemnopsis tanganensis (Futt.).
Rhopaloteuthis aff. *spissa* (Gill.).

With these are associated lamellibranchs and gastropods among which are *Pleurotomaria* sp., *Gryphaea balli* (Stef.) (the most abundant ; found in the basal Kimmeridgian of Somaliland), *Exogyra fourtaui* Stef. (ditto), *Chlamys* sp. *Ctenostreon proboscideum* (Sow.) (a well known English Corallian form), *Plicatula* sp., and *Pleuromya uniformis* (Sow.), (regarded by Mr. Cox as synonymous with the well known *P. tellina* and others.) The brachiopods belonging to this stratigraphical level are : *Rhactorhynchia ? attookansis* Muir-Wood, '*Rhynchonella' brevicostata* Kitch. (a Cutch form found in the Dhosa Oolite), '*Terebratula jhalarensis* Muir-Wood, *T. punjabiensis* Muir-Wood, and *Lophothyris*

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[1] *Pal. Ind.*, New Ser. XX, Mem. 6, 6-10 (1937).

euryptycha (Kitch.) (found also in the Dhosa Oolite of Cutch)[1]. The poorly preserved ammonites of this Argovian fauna mostly belong to species known in the Upper Dhosa Oolite and the equivalent Kantkot sandstone of the Cutch Jurassic. This fauna shows closer affinities with the Indos-Malagassy province than with that of the Mediterranean area ; although equivalent in horizon to part of the Spiti Shales, none of its lamellibranchs is identical with those which characterise this Himalayan formation.

The next higher assemblage comprises three limonitic specimens of ammonite from one mile east of Burjianwala Laman, *viz.*, *Blanfordiceras wallichi* (Gray). *Aulacosphinctes* cf. *proximus* (Steuer) and *Spiticeras* sp., an ammonite fragment identified as *Blanfordiceras* cf. *böhmi* (Uhl.) from near Talidhok, and a few lamellibranchs mostly from the former locality, *Trigonia ventricosa* (Krauss). *T.* cf. *retrorsa* Kitch. and *Plicatula* cf. *radiola* Lam. The ammonites belong to species found only in the Lochambel stage of the Spiti Shales, and the lamellibranchs confirm a position at the base of the Neocomian.

The highest fauna in these Attock beds belongs really to the Giumal series which belongs to the Cretaceous. The Giumal fauna of Attock is under examination.

CHITRAL AND THE PAMIRS.

Chitral.—The high mountainous country comprising the upper valleys of the Lutknh and Arkari in northwestern Chitral, is occupied by garnet schists, sillimanite and chiastolite schists and bands of crystalline limestone, a rock assemblage which represents an altered sedimentary series. The alteration is the effect of intrusions of a white, garnetiferous granite, which may be parallel to the foliation planes of the schists or may cut them at all angles, the final result being a breccia of schist and granite on a large scale[2].

In the upper part of the Arkari valley the amount of intrusive material is small and metamorphism much less. The schists are replaced by comparatively soft shaly beds and, in the Nuqsan Pass (16,000 feet) Mr. Tipper collected a complete belemnite and fragments of two others. Probably the schists belong to more than one system, but the fossils prove that the beds are in part of Mesozoic—probably Jurassic—age.

Pamirs.—In the Pamirs, to the north of the Wakhan Province of Afghanistan, the Sarikol Shales (which,) with their " needle " weathering and abundant concretions so strongly resemble the Spiti Shales, are regarded provisionally as older ; the concretions have so far yielded no fossils[3].

In the Kakcheki (Kekchaki), a small tributary valley of the Aksu, not far from the Lakhshakh Pass, a hard, grey, siliceous, brown-weathering limestone was observed by Hayden overlying the Pamir Limestone. The siliceous limestone, which is thin-beded and highly jointed, was found to contain ammonites, consisting chiefly of *Perisphinctes* most of which, in Hayden's opinion, would formerly have been referred to the comprehensive form *P. polyplocus* Rein. A cursory examination suggested the presence of forms allied to *P. frequens* Opp.. and *P. lothari* Opp. Other specimens appeared to belong to the genera *Oppelia* and *Reineckeia* one of them closely resembling Steinmauns' *Reineckeia brancoi* ; a belemnite fragment was also picked up. Hayden concluded that the general facies of the fauna is Callovian.[4] In one section this Jurassic limestone stands up in great slabs, the surfaces of which are covered with ammonites, and lie in a sharp syncline with an almost vertical southerly limb upon the Pamir Limestone. At the head of the Kekchaki valley the Perisphinctes limestone is overlain by other limestones and oolites which may be of Cretaceous age.

Further west fragmentary and badly preserved fossils, similar to those of the *Perisphinctes* bed of Kekchaki, have been observed about three miles west of the Ayujuli Kotal between Aktash and Salangur, and again at Karasu on the main road from the Alichu Pamir to Post Pamirski, where the fossils occur in dark thin-bedded limestones[5].

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[1] *Pal. Ind.*, New Ser. XX, *Mem.* 6, 16—23, 1937.

[2] Gen. Rep. *Rec.*, LV. 38-9 (1923).

[3] H. H. Hayden. *Rec.*, XLV, 305, 307 (1915).

[4] *Ibid.* 307-9 (1915).

[5] *Ibid.* 312—313.

On the right side of the Gurumdi valley, opposite Kengshubar-uch-kol, lying upon a massive limestone which is presumably the Pamir Limestone, Hayden discovered some dark grey, very hard, well-bedded limestones, in places oolitic, occurring in beds of about one foot in thickness. Above these comes a calcareous shale, very crushed and often slaty, which has yielded a few very crushed and badly preserved belemnite fragments composed of white, crystalline calcite. *Perisphinctes* was not found at this locality but Hayden has suggested that the *Belemnites* belong to the upper part of the *Perisphinctes* bed.

MADHAN SLATES OF THE SIMLA AREA.

In the tectonic window of the Shali area, to the northeast of Simla, beneath the Chail Thrust is a sequence composed, as already stated, of the Shali series, the Madhan Slates and Tertiary beds.[1] The first two of these three formations are unfossiliferous and of unknown age. If the Shali correspond to the Krol series, for which a Triassic age has been suggested, the Madhan Slates, so named by Captain Palmer, would fall somewhere between the Trias and the upper Eocene (Subathu) and might belong to the Jurassic, but this correlation is scarcely more than surmise.

In places the Chail rocks have been thrust over the Shali beds but between the Pandoa Khad and Nag Tikar, the prominent peak northeast of the Shali, the Madhan Slates make their appearance, lying upon the Upper Shali Limestone, the highest stage of the Shali series being absent ; this uppermost stage, the Shali quartzite, however, comes in a little further on. In other parts of the window, beneath the Chails the Eocene beds are to be seen lying unconformably upon the Madhan Slates.

The Madhan is a highly folded slate series, to which the only beds that show any resemblance are the very variable Jaunsar series. The most frequent types are rusty brown or grey, finely jointed slates, showing occasional smooth planes in which a green mica has developed. Interbedded with these are greyish or whit quartzitic sandstones, in the midst of which occur beds of blue clay dug out by villagers for plaster-making. Vein quartz is frequently found in all these beds. Beds of purple gritty quartzite and purple shale are in many places included in the sequence as well as cream and lavender slaty shales.

THE TAL SERIES OF SIRMUR AND GARHWAL.

This is a convenient place in which to describe certain beds which underlie the Nummulitics in southwestern Garhwal and are not entirely unfossiliferous. Originally discovered by Mr. Medlicott in the Tal valley immediately east of the Ganges, they are consequently referred to as the Tal beds, and are interesting by reason of the fact that they contain the only Pre-Tertiary organic remains hitherto recorded in this section of the Lesser Himalaya, south of the main snowy range[2]. The mapping of Middlemiss and Auden has shown that the Tal beds occur in four separate basins, extending over a total length of outcrop of 110 miles[3]. West of the Tons river, on the north side of the Giri, the same beds have been recognised to the northeast and east of Dadahu by Mr. J. B. Auden who distinguished in them two subdivisions. In this eastern part of Sirmur State the beds occupy two synclinal basins, their outcrops being entirely surrounded by beds of the Krol series on which they rest stratigraphically. The scenic changes from the rugged, cream-white limestones of the uppermost stage of the Krol series to the soft, dark shales and graywackes of the Lower Tals, and from these to the pale, cliff-forming Upper Tal quartzites are described as striking[1]. The beds have been divided as follows [2]:

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[1] Gen. Rep. *Rec.*, LIII, 1 (1921) ; *Ibid* LXI, 26 (1928) ; *Ibid* 74, 133—163 (1939).

[2] *Mem.*, III pt. 2,69 (1864).

[3] Gen. Rep. *Rec.*, 72, 82 (1937).

Upper Tals.	Dark limestones and calcareous sandstones; quartzites; shales. Massive arkosic sandstones or quartzites; pebble beds; shales. Alternating quartzites, often pebbly, with shale or slate.
Lower Tals.	Micaceous shales or slates with a few quartzites. Thick series of carbonaceous shales and dark graywackes, in massive beds marked out by finer banding and current-bedding. These pass laterally to tough slates and phyllites. Black chert beds and carbonaceous shales or slates.

The thickness of the Lower Tals in the western basin varies from about 1,800 feet at the western end to 3,500 feet at the eastern; in the eastern basin it probably does not exceed 2,000 feet. In their slaty form the Lower Tals can be mistaken for the Infra-Krols; when uncleaved they are usually distinguishable from this formation by their more massive bedding and by the abundance of dark graywackes, many of which are highly calcareous. The carbonaceous shales readily bleach, but in a uniform manner and not in rings as they do in the case of the Infra-Krols. Ripple-marks are sometimes seen.

In the eastern basin the Upper Tals, when not reduced by thrust-faulting, are about 2,000 feet thick; in the western basin, where the sandy limestones at the top have been preserved, the thickness is probably greater. The most characteristic strata of the Upper Tals are quartzites which vary in colour from white to pale green and are generally arkosic; purple sandstones are occasionally found. Current bedding is universal and ripple-marks are common. Many of the sandstones are pebbly, the pebbles consisting of vein-quartz, green slate and abundant pink felspar, the latter up to 10 mm. in length. The felspar ingredient shows a decrease in coarseness from west to east. The micaceous shales interbedded with the quartzites are purple, red and green in colour; some of them show evidence of exposure to the air and represent sun-cracked mud whose turned-up edges became filled in with later sand-washings[3]. In proximity to the Guma thrust fault the shales have been converted to puckered phyllites. In the northern part of the western basin clay slates are common. The limestones, unfossiliferous in these Sirmur exposures, are always dark, sandy and current-bedded. Over the Tal rocks east of Dehra Dun two units have been thrust, one consisting of Mandhali beds and the other of Chandpurs[1]. A fossil band found by Auden in the Dehra Dun district, between Silla and Rigalgarh, probably occupies the same position as that found by Middlemiss in the Upper Tal limestone east of the Ganges; it is a dark shelly limestone full of broken lamellibranchs and brachiopods.

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[1] J. B. Auden. *Rec.*, LXVII, 385 (1933).

[2] The Upper Tals of Auden's scheme include both the Lower and Upper Tals of Middlemiss; Auden's Lower Tals are practically absent in the area mapped by Middlemiss, *i.e.*, in Garhwal.

[3] J. B. Auden, *Rec.*, LXVII, 385 (1933).

The Tal series, corresponding almost entirely to the Upper division of the formation, has been recognised by Middlemiss in the Lesser Himalaya east of Hardwar, in continuation of the sections in the Tal, a tributary of the Ganges, discovered by Medlicott, and again 25 or 30 miles to the southeast, in the Pillani valley, south of Lansdowne hill station. In the former of the two areas the Tal beds lie unconformably upon an older series of purple slates and boulder-beds, the two being folded up together and thrust over the Siwaliks along the great boundary fault; separating this belt from the crystalline schists of the higher slopes is a thin band of nummulitic shale. Below Lansdowne the Tal beds lie beneath a massive limestone, [2] and again along the other boundary are in contact with the narrow band of nummulitic shale.

In Garhwal the Lower Tals are practically absent. Fossils were found by Middlemiss in a rock varying from a grit to a quartzite, with here and there a tendency to become calcareous or conglomeratic. The fossils, found on the west bank of the Pillani river, comprise corals, belemnites, lamellibranchs and gastropods, usually all of small size, and indicating a Mesozoic-probably Jurassic age. The basal rock is a rather coarse millstone grit, with quite distinct, slightly angular quartz grains, of a milky white or smoky colour, set in a pale yellow, earthy matrix; on weathered surfaces the white grains of quartz stand out against a black background, unlike any other rocks in the neighbourhood. The conglomerates differ merely in the larger size of the quartz fragments which retain their slight angularity. The calcareous varieties never become pure limestones but always show the blebs and grains of quartz on an indigo-black weathered surface[3]. This coarse grit, with its calcareous and conglomeratic varieties, passes up by insensible gradations into a white or faintly violet, compact, massive quartzite of large thickness.

The Jaunsars and Upper Tals were, in the opinion of Auden, probably formed under almost identical delto-continental conditions, and are closely similar in character. The Upper Tal quartzites as compared with those of the Jaunsar series are generally whiter, less horny, not so markedly permeated by quartz, poorer in plagioclase and not nearly so rich in tourmaline. The shales and clay-slates of the Upper Tals lack the phyllitic and tough slaty condition usual to the corresponding types in the Jaunsars.

THE NAPENG AND THE NAMYAU FORMATIONS OF BURMA.

Age.—In the Northern Shan States of Burma two more or less associated formations have now to be considered, are known as the Napeng stage and the Namyau series. Until recently the former had been regarded definitely as of Rhaetic age and the latter as belonging to some higher stage of the Jurassic, probably to the Callovian or Cornbrash. The question of their age will be more fully discussed in the sequel. Suffice it to say for the present that although, for various reasons, it has been suggested by the French geologists of Indo-China, who have recorded correlatable beds in several parts of that country, that the Napeng and Namyau are but different facies of the Noric or Upper Trias; this suggested change of view is not in every way acceptable and the two Burmese formations are retained, for the present at least, in the stratigraphical position hitherto assigned to them. At the same time, it is admitted by LaTouche, who christened the Burmese rocks, that sections in the field are everywhere so obscure that the exact relations between the two formations have not yet been ascertained[1]. The Napeng stage has an individuality cf its own and is readily distinguished from the Namyau series.

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[1] Gen. Rep. *Rec.*, LXXI, 74 (1936).

[2] Described as "of Krol type." *Rec.*, XVIII, 76 (1885).

[3] C. S. Middlemiss, *Rec.*, XVIII, 74 (1885).

THE NAPENG STAGE.

(i) HISPAW NORTHERN SHAN STATES.

Introduction.—Above the Plateau Limestone in Burma comes an important break, and there is a gap between the top of this formation and that which follows which, if not of Rhaetic age is not likely to be older than Upper Trias. After the deposition of the Plateau Limestone, probably during some part of the Triassic period, the Shan-Yunnan area was elevated to form land, which became worn into hills and hollows before being again submerged. In the hollows then accumulated the Rhaetic shales and limestones. This renewed submergence of a country of raised reefs was elsewhere characterised by the sporadic deposition of coarse beaches made up of well rolled pebbles of the Plateau Limestone as well as of older underlying rocks. The beds next laid down are very different in character from the beach conglomerates and from the Plateau Limestone, and are capriciously distributed as well as variable in composition. That parts of the plateau region of Burma lay beneath the sea as late as Cretaceous times is proved by the marine fossils of that age recently discovered in one of the Northern Shan States

Lithological Composition.—The prevailing type of the Napeng beds is a yellow or variegated shale or indurated clay, not unlike the Devonian Wetwin Shales in appearance. In places it is impregnated with calcareous matter and passes into clunchy sandy marls or tough, thin-bedded, argillaceous limestones. Interstratified with the shales of this formation, especially at or near its base, are beds of hard, dark blue limestone which, when it contains no visible fossils, is indistinguishable from some of the Permian varieties of the Plateau Limestone. Occasionally fossils are to be seen weathered out on the surface, but the only determinable remains are those of one or two corals; in thin sections the rock is seen to be crowded with fragments of shells, echinoid spines and foraminifera[2].

Distribution.—About half-a-dozen patches of these rocks of varying size are scattered over the State of Hsipaw, in most cases as outliers, accompanied or not by the younger Namyau beds, upon the Plateau Limestone. The relations of the Napeng beds to the rocks both above and below are described as obscure[3]. The eastern boundary of the Namsaw outcrop is mapped as an unfaulted contact partly with the Naungkangyi series (Ordovician) and partly with the Namhsim sandstone (Silurian). The largest outcrop is that which has furnished most of the fossils and lies to the east and southeast of Napeng, a small village after which the formation has been named. Two outlying patches lie far to the east, on the southern flanks of the Loi-len range, and another very small exposure is situated near Man Sam on the trade route leading north from Hsipaw. A patch of Napeng beds exposed in the neighbourhood of the Shan village of Na Keng is the most northerly one so far known.

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[1] *Mem.*, XXXIX, pt. 2, 286 (1913).

[2] *Ibid.* 285.

[3] Gen Rep. *Rec.*, XXXVII, 23 (1908).

Mode of accumulation.—The general absence of the Napeng beds between the extensive outcrops of the Namyaus and the Plateau Limestone on which they repose can scarcely be due to partial denudation of a continuous formation, and appears rather to indicate restricted deposition of the older stage. La Touche visualises during the Rhaetic epoch "a wide expanse of coral reefs, raised for a period to a sufficient height above sea-level to be exposed to denuding agents and worn into ridges and hollows, many of the latter perhaps cup-shaped depressions similar to those which are being formed at the present day. If an irregular surface of this kind were gradually covered by the waters of the sea so as to be just awash, it would be natural that the sediment, most of it of an extremely fine character derived from the residue left by the degradation of the limestones still above water, would silt up the hollows, some of which might be at times cut off from communication with the open sea or from each other". Such localization in deposition would at the same time account for certain peculiar variations in the nature of the fauna. While many of the shells, for example, in the broad Napeng area are of large size and some of them especially-those of *Gervillia* and *Myophoria* are very massive, those in the small Loi-len patches are ill-developed, extremely thin and stunted in size ; according to La Touche the latter deposits may have been formed in small, more or less isolated depressions in which suitable food was scarce. Again, two miles north of the first railway station east of the Gokteik Gorge-Nawngping–a bed of shale exactly similar to that of Napeng has yielded a meagre fauna which may well belong to the same epoch but is totally different in character from the normal fauna, and consists of indeterminable fragments of decapod crustacea—prawns and shrimps of unknown genus—fragments of a large *Posidonomya* and a small *Lingula*. On the opposite side of the railway line La Touche found what he deduced to be the edge of an old depression or "sink-hole" in the Plateau Limestone, lined with a calcareous deposit containing numerous casts of minute gastropods and bivalves of Lower Jurrasic age—*Pteria* sp., *Worthenia* sp., *Loxonema* (?) sp., *Actaeonina* (?) sp.; this calcareous lining has every appearance of being an ancient tufa or travertine deposited around the edges of the sink-hole while the more central portion was being filled up with silt.

The Napeng beds are occasionally horizontal or nearly so, but their characteristic structural feature, according to Dr. Coggin Brown, is extreme disturbance ; such contortion and disturbance are especially noticeable in the type area and, irregular though they are, are probably attributable to earth movement and not to underground solution of the limestone floor, as was at first suggested.

Fauna.—Most of the members of the copious Napeng fauna are crushed and distorted. The following is a list of the forms determined by Miss Maud Healey[1].

ANTHOZOA.—

Lophosmilia praecursor Heal.,
Isastraea confracta Heal.,

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[1] *Pal. Ind.*, New Ser., vol. II, Mem. 4, (1908).

BRACHIOPODA.—
Lingula nanimensis Heal.

LAMELLIBRANCHIATA.—
Palaeoneilo fibularis Heal. (Closely resembling *Leda tatei* Newt., Lower Lias of Arran),
,, *nanimensis* Heal.,
,, *curvirostris* Heal.,
,, *whitchurchi* Heal.,
Nucula peelii Heal.,
Grammatodon lycetti Moore.,
,, (*Catella*) *laticlava* Heal. (Strikingly like *Arcoptera canaliculata* Kittl. from the Upper Muschelkalk of Yugoslavia),
Pinna cf. blanfordi Boettg., (Rhaetic, Sumatra),
Conocardium superstes Heal.,
Gervillia shaniorum Heal.,
,, *praecursor* Quenst. (Rhaetic, Europe),
,, *rugosa* Heal.,
,, *napengensis* Heal.,
Hoernesia filosa Heal.,
Cassianella cf. *subspeciosa* Mart. (Rhaetic, Europe),
Perna obruta Heal.,
Pteria (*Avicula*) *contorta* Portl. (Rhaetic, Europe. Of wide distribution in the Napeng beds),
Alectryonia cf. *haidingeriana* Emm. (Rhaetic, Europe),
Myophoria napengensis Heal. (Abundant, and showing considerable variation; belongs to Frech's group of *M. costata* Zenk. cf. especially *Hemicardium myophoria* Boettg. of the Rhaetic, Sumatra),
,, *tenuis* Heal. (Close to *M. chenopus* Laube which is difficult to distinguish from *M. inequicostata*, both from the Upper Trias of the Alps),
,, cf. *emmerichii* Winkl. (Rhaetic, Europe),
Pecten (*Syncyclonema*) *quotidianus* Heal. (Belongs to the Triassic and Rhaetic group of Pectens),
,, (*Aequipecten*) *bayzandi* Heal.,
Plicatula (*Pseudoplacunopsis*) *carinata* Heal.,
,, *difficilis* Heal.,
Placunopsis cf. *mortilleti* Stopp. (Rhaetic, Europe),
Anomia napengensis Heal. (cf. *A. irregularis* Terq. from the Lower Lias Europe),
Modiolopsis gonoides Heal. (Identical with the casts known as *Plenrophorus elongatus*(?)),
Modiola frugi Heal. (Moore, from the Malay Peninsula),
Burmesia latouchei Heal. (Genus related to the Pholadomyacidae and Anatinidae),
,, *lirata* Heal.
Prolaria sollasi Heal. (Genus allied to *Burmesia*),
Thracia prisca Heal.,
Cuspidaria sp.,
Datta oscillaris Heal. (A new genus),
Astarte sp.,
Isocyprina cf. *ewaldi* Bornem. (Rahaetic and Lias, Europe),
,, *manca* Heal.,
Cardita singularis Heal.,
Dentilucina mona Heal.,
Protocardia contusa Heal. (Very variable; close to *P. choffati* Bohm, Lower Lias of Portugal, to *P. phillippiana* Dunk, Lias, Europe, and to *P. rhaetica* Mer. from the British Rhaetic),
Cardium nequam Heal.,
Conocardium ? sp.

SCAPHOPODA.—
Dentalium sp.

GASTROPODA.—
Promathilda exilis Heal. (Very close to *P. ammoni* v. Wohr., *P. stuorensis* Kittl. and *P. antonii* Kittl. from the Uper Trias of Europe; and to *Cerithium martinianum* d' Orb. and *Turritella humberti* Mart. from the Lower Lias of Europe),
,, *acedesta* Heal.,
Turritella (*Mesalia*) sp.,
Loxonema sp.,
Scalaria (?) *exigua* Heal.,
Moerkeia (?) *burmensis* Heal.

The above fauna comes from the shales. One of the bands of limestone near the base of the stage is seen, when sectioned, to contain numerous minute foraminifera including representatives of the Lituolidae, Miliolidae and Textulariidae. We know nothing more than this of the fauna which built up the limestone bands except that sections of brachiopod and gastropod shells and of echinoid spines are not uncommon in places; the predominance of lamellibranchs in the shales, to the almost complete exclusion of other forms, therefore, is probably due to, or exaggerated by, the solution and obliteration of the latter to form the limestones.

Mr. La Touche calls attention to the significant fact that, whereas in the Padaukpin, Wetwin and Permian faunas found at varying levels in the Plateau Limestone, only 15·5, 26·6 and 7·7 per cent. respectively of the species were new forms, in the case of the Napeng assemblage no less than 53 per cent. were found to be new; not only was this the case but it was also found necessary to establish three new genera among the Napeng specimens, *Datta*, *Burmesia* and *Prolaria*.

The abundance of such genera as *Myophoria*, *Pecten* and *Cardium*, give a Mesozoic character to the fauna, and the Rhaetic age of the latter was considered to be definitely proved by the presence of *Pteria* (*Avicula*) *contorta* Portl., the zone fossil of the stage, and of *Grammatodon lycetti* Moore and *Gervillia praecursor* Quenst., both characteristic fossils of the same horizon, as well as of several species closely resembling Rhaetic forms, such as *Cassianella* cf. *subspeciosa* Mart., *Isocyprina* cf. *ewaldi* Bornem., *Myophoria* cf. *emmerichi* Winkl. and *Placunopsis* cf. *mortilleti* Stopp. At the same time the assemblage includes what must be looked upon as three survivals from Palaeozoic times in the genera, *Conocardium* (?) *Modiolopsis* and *Palaeoneilo*. The presence of the last, an American genus, particularly abundant in the Devonian Wetwin Shales, as we have seen, intensifies the close resemblance which these shales lithologically bear to the more argillaceous portions of the Napeng beds; in fact, the two sets of beds, although of different age, appear to have been deposited under much the same conditions and to owe their peculiarities to unusual bionomical surroundings.

Recently the doubts which originally surrounded the age of the Napeng beds have been revived. Out of 40 species composing the Padang series of western Sumatra, a formation whose neo-Triassic age is claimed to be clearly determined, 11 exhibit a close ressemblance to the most abundant and most characteristic Napeng forms, such as *Gervillia praecursor* Quenst., *Syncyclonema quotidianus* Healey, and *Myophoria napengensis* Healey. The same similarity is seen in the Misol fauna of the Moluccas which is assigned to the uppermost Trias by reason of its cephalopods, *Neotibetites*, *Sagenites* and *Sibirites;* out of 39 species, six are Napeng forms. Again the Tembeling series of Singapore has yielded *Syncyclonema* sp and casts of *Modiolopsis gonoides* Healey, but not *Pteria contorta* ; for these beds Mr. R. B. Newton has suggested an Upper Triassic or Rhaetic age, Dr. Weir an infra-Rhaetic[1]. Lastly a fauna including a lamellibranch which, if not absolutely identical with *Myophoria napengensis* Healey, is no more than a variety of this variable form, and other typical Napeng species, has been recorded in a few localities in Laos and Tonkin. At Con Tagne, some 60 miles away from the Shan States border, a series of clay shales, resting on limestones of Palaeozoic appearance, have been found by M. Jacob and Dussault to contain a typical Napeng fauna including many species of the *Myophoria* and of *Pecten quotidianus* ; out of 13 species identified by Capt. Patte no less than 8 are typical Napeng forms and 3 are closely allied[2]. A comparable form to the Rhaetic fossil, *Pteria contorta*, is a member of this assemblage which is so closely akin to the Burmese fauna as to deserve being recorded in full :

LAMELLIBRANCHIATA.—
Grammatodon contagnensis,
Hoernesia filosa Healey,
,, sp. (the equivalent of Miss Healey's *Cassianella* sp. No. 3.),
Avicula (*Pteria*) cf. *contorta*,
Cassianella dussaulti,
Myophoria napengensis Healey,
,, *emmerichi* Winckler,
Pecten quotidianus Healey,
Burmesia lirata Healey,
Thracia prisca Healey,
Cardita singularis Healey,
Cardium aff. *nequam* Healey,
Protocardia aff. *contusa* Healey.

At Muong The, in addition to the Burmese spieces, *Lingula nanimensis*, *Burmesia lirata*, *Pecten quotidianus*, and *Cardita singularis*, and to other forms comparable to Napeng species, there have been found three Himalayan Noric fossils, the lamellibranch *Anodontophora griesbachi* Bittn. and the two ammonites *Anatibetites* cf. *kelvini*, and *Tibetites* aff. *perrin smithi* Mojs. Although the two ammonites are only comparable or related forms, their genera are said to be unknown outside the Noric stage, and it is mainly on the strength of these two cephalopods that the French geologists, more especially M. Fromaget, have come to regard the Napeng fauna as Noric[3]. So far as the somewhat conflicting evidence goes, it seems not unlikely that the beds we have been considering all belong to a formation which, although striding as a whole an appreciable thickness of the stratigraphical column —Upper Trias to Rhaetic and perhaps beyond—is represented by fragmentary and sporadic deposits differing from one another in age to a small degree although possessing a strong family resemblance in their separate faunas. The fauna at Muong The, for instance, has yielded the following assemblage determined by Captain Patte :

BRACHIOPODA.—
Lingula nanimensis Healey, (Napeng).
LAMELLIBRANCHIATA.—
Pecten tonkinensis Mansuy.,

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[1] J. B. Scrivenor. "Geology of the Malay States," 64 (1931).

[2] *Mem. Serv. geol. Indo-chine*, vol. IX, fasc. 1,44 (1922) *Bull. Serv. geol. Indo-chine*, vol. XIII, fasc. IV, 43. (1924).

[3] *Bull. Serv. geol. Indo-Chine.* vol. XVIII, fasc 5 ; J Coggin Brown, *Rec.* LXXI, 192. (1936).

Burmesia lirata Healey, (Napeng),
Cardita singularis Healey (Napeng),
Palaeocardita aff. *crenata* Goldf. (Ladinic of St. Cassian),
Anodontophora aff. *trapezoidalis* Mansuy (Trias of Na Cham),
Myophoria napengensis Patte non Healey, (Napeng),
,, aff. *costulata* Bittn. (Lower Trias),
Cassianella angusta Bittn. (Ladinic and Upper Trias.)
CEPHALOPODA.—
Anatibetites cf. *kelvini* (Himalayan Noric),
Tibetites nov. sp. aff. *perrin-smithi* Mojs. (Himalayan Noric).

and in the same band elsewhere, a form very characteristic of the Himalayan Noric, *Anodontophora griesbachi* Bittn.

Considerable though the resemblances are to the Napeng, there seems no reason against regarding this Muong fauna as belonging to an older stage of the series, of which the beds at Napeng form a part. *Pteria contorta* is absent from the former, just as the Noric ammonites are missing from the Burmese beds. Until something more definite is known of the inter-relationship of all these faunas, it seems preferable to restrict the term Napeng stage to the beds at Napeng and Con Tagne and to regard them provisionally as Rhaetic and probably younger than the other beds referred to above in Indo-China, Sumatra and Moluccas. The fauna from Kuang-shang, about four miles from Naku, in southern Yunnan, suggests in some respects the Napeng beds but, like the Indo-Chinese, Sumatran and Moluccan has more Triassic than Rhaetic affinities ; it has been described under the heading of Trias (p.902). The statement that the Napeng fauna has a comparatively wide distribution in southeast Asia is not strictly true if the term be restricted as suggested, but there is no doubt that the changes in the relations of sea and land which accompanied the deposition of the beds in the Shan States must have affected also considerable areas in Indo-China, Yunnan and elsewhere either during or just before the same epoch.

(ii) NORTH HSENWI.

Northwards, in north Hsenwi, according to Mr. Hobson, the Plateau Limestone appears to pass up through passage beds into a fossiliferous Rhaetic stage. The "passage beds", for which a Noric age is suggested, consist of dark grey, unfossiliferous, thin-bedded limestones with inter-bedded sandstones passing up into carbonaceous sandstones[1].

The Rhaetic beds, exposed in the neighbourhood of the Shan village of Na Keng, comprise yellow or purple clays, grey shales, dark blue, compact limestones and grey, argillaceous limestones. These beds have yielded an interesting fauna which, while indicating affinities with the Napeng fauna through such forms as *Palaeoneilo nanimensis* Heal., *Dentilucina mona* Heal., *Promathilda exilis* Heal., and *Pecten bayzandi* Heal., is, on the whole, distinct therefrom. The absence of the Burmesiidae and of the zone fossil, *Pteria* (*Avicula*) *contorta* Portl. is significant. The majority of forms belong to undescribed species. Of the lamellibranchs there are *Modiola*, *Cardium*, *Protocardium* and a new species of *Pecten* ; a single specimen of *Posidonomya* has been obtained. Of gastropoda a new species of *Pleurotomaria* occurs very profusely in one of the limestones[2]. The beds occupy a tract about 26 miles long, north of the Nam Tu.

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[1] Gen. Rep. *Rec.*, LXIII, 92 (1930).

[2] Gen. Rep. *Rec.*, LXV. 87-88 (1931).

In the Himalaya no trace of a Rhaetic fauna has so far been discovered in the Megalodon or Kioto limestone ; either there was no deposition during that epoch, or its organic remains have suffered complete solution to unfossiliferous layers of limestone. We have no means, therefore, of comparing the life assemblages of the two regions ; all that is certain is that the shaly facies of the Burmese Rhaetic is not present in Kumaon, Spiti and Kashmir.

NAMYAU SERIES.

HSIPAW STATE.

Relationships.—In the one or two exposures where the Namyau beds are in contact with the Napengs, no sign of a stratigraphical break has been noted. It has always been assumed, chiefly on palaeontological grounds, that the Napeng is older than the Namyau formation but, although the latter is spoken of as following the former, the mutual relationships of the two formations are described as obscure[1]. It has been claimed that fossil evidence points to a gap between the two, covering a considerable period of time and represented in other parts of the world by several thousand feet of strata. Recent work in Indo-China, however, tends to minimise the difference in age, and a careful revision of the Namyau faunas and the establishment of their correct stratigraphical position in the formation are desirable. The non-sequence between the Napeng stage and the Namyau series is emphasised by a well marked contrast in lithological character. In most cases the floor of the Namyau sediments is the Plateau Limestone, and here the junction is one of unconformity[2].

Distribution.—The Namyau formation, which is an easily eroded one, must have once covered a very much wider area than it does today ; no occurrence of it is known west of the Gokteik Gorge and the western part of the Shan plateau is entirely devoid of its sediments. A broad belt of these rocks strikes through the town of Hsipaw, with a general N.N.E.-S.S.W. direction, for over 50 miles with a maximum breadth of 16 miles, and occupies a long section of the Mandalay-Lashio railway line ; the series is especially well developed in the valley of the Namyau river.

The beds crop out again east of Lashio, and there are three or four smaller outliers on the Hsipaw plateau to the east of the main belt. These are all patches of what was once a wide continuous spread of these rocks. Only in two places do the Napeng beds intervene between the Namyaus and the Plateau Limestone. On nearly every side and throughout nearly the whole of its length the main exposure of Namyau beds is in contact with the Plateau Limestone ; towards the south the boundary on both sides is faulted but northwards it is that of a large outlier upon the limestone, and as such it must be regarded, lying unconformably and owing its preservation, partly at any rate, to the faults which have let it down into the levels of the limestone. One outcrop of the Namyaus in the northern part of South Hsenwi overlaps the Plateau Limestone on to the Chaung Magyi rocks ; along its northern boundary it is in faulted contact with these old rocks.

Lithological Character.—Forming the base of the series are banks of coarse conglomerate which, however, are by no means continuous and appear to mark the position of local beaches. Good examples are to be seen in the Nam Tu, a short distance above the Ta-ti ferry which lies on the trade route leading north from Hsipaw, and also at Htengnoi lower down the same river. This conglomerate consists of well rolled pebbles of the Plateau Limestone and of the more ancient rocks, set in a sandy, calcareous matrix.[1] The rest of the series consists essentially of sandstone, with quite subordinate thin bands of clay and, in the lower portion of the sequence, thin bands of limestone. Most of the clay bands are of a red colour and occur throughout the whole thickness of the formation, sometimes between the limestone bands ; occasionally they are carbonaceous. The total thickness of the clay bands, like that of the limestones, bears a very small proportion to that of the sandstone, and the sub-division of the series suggested by Buckman into the Namyau Limestones below and the Namyau Shales above is quite untenable.[2]

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[1] T. H. D.La Touche *Mem.*, XXXIX, pt. 2, 286 (1913).

[2] J. Coggin Brown. *Rec.*, XLVIII, 154 (1917).

The whole of the Namyau series is distinguishable by its dark red or purplish colour, though pepper-and-salt sandstones and yellow clay bands are occasionally interstratified especially in the higher levels. The sandstones, as a rule, are soft and friable, seldom hard enough to be used for building purposes, and sometimes beautifully ripple-marked. The limestone bands, none of them more than a few feet thick, are very uniform and often persist for several miles. They are very compact and fine-grained, often argillaceous and abounding in fossils, passing into shelly limestones. Being easily weathered these limestone bands form no conspicuous feature on the surface but, by their vertical position or generally high angle of dip, witness to the disturbance the rocks have undergone.

Physiography.—The sandstones yield readily to denudation and invariably occupy an intricate net work of ridges and ravines with no marked uniformity in direction, covered with dense and almost trackless forests. The magnificent falls of Manlong-Mansang on the Namyau river owe their existence to the more rapid erosion of the red Namyau beds as compared with that of the Plateau Limestone, against which they are let down by a fault crossing the river at the base of the falls.

Thickness.—Several thousand feet of the Namyau beds have survived denudation, but the obviously enormous amount of erosion, the absence of continuous sections and of an upper limit, coupled with the great disturbance of the beds and the prevalence of faulting, make even an approximate estimate of the total original thickness impossible.

Fauna.—Fossils from this formation, extracted by roasting[3], have been collected almost entirely from the bands of limestones, which are said to predominate in the older portion of the succession. Following the implication of early surveys Buckman suggested that the Namyau series could in this way be divided into a lower and an upper division, the latter made up mainly of shales and the former mainly of limestone bands, from a few of which are derived the fossils so far examined. According to La Touche (private communication) the so-called shale bands, which are really bands of clay, are scattered throughout the whole formation which is mainly arenaceous, and some of the later surveys seem to point to a more even distribution of the limestones also. The rich brachiopod collections, which quite possibly come from more than one horizon—a suggestion borne out by internal evidence of the assemblage itself—have been examined by Mr. S. S. Buckman, who is of opinion that they indicate a Bathonian age (Great Oolite to Cornbrash). According to Dr. Cowper Reed, both from their affinities and the nature of the matrix in which they occur, the few lamellibranchs[1] examined by him belong to two slightly different horizons; the older of these, a greenish, compact, calcareous mudstone with scarcely any brachiopods is assigned by him to the Bathonian, while the younger, composed of a bluish, argillaceous limestone or blue clay with abundant brachiopods[2], possesses a lamellibranch fauna suggestive of the Cornbrash[3]. Incidentally the latter is considered to be equivalent to a small fauna collected by Coggin Brown in Yunnan. The genus *Burmirhynchia* has since been found widespread in Europe, Africa and other parts of the world in the Callovian and Bathonian. On the other hand, *Holcothyris*, a sub-genus which shows close resemblances to *Aulacothyris*, has so far not been found outside the Shan States and Yunnan[4]. It is remarkable that not a single cephalopod of any kind has been found in the Namyau rocks of Burma to match the copious ammonite faunas of the Himalaya and Cutch, belonging as they are supposed to do to much the same part of the Jurassic period. Mr. Buckman's list of brachiopods, partly amended by Dr. M. R. Sahni, is as follows[5]:

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[1] T. H. D. La Touche. *Mem.*, XXXIX. pt. 2, 303(1913).

[2] Private communication from Mr. La Touche. *See* also M. R. Sahni. *Rec.*, LXXI, 227 (1936) ; *Pal. Ind.*, New Ser., vol. III, Mem., 2, 215 (1917) ; Also C. S. Fox. *Rec.*, LXIII, 185 (1930).

[3] Probably Mr. La Touche was not the first to discover this ingenious method of fossil extraction but his description of the process has led to astonishingly successful results, especially in the examination of internal structures, and palaeontologists are under a debt to him and to the Shan cooly who unwittingly guided him to the discovery. *Mem.*, XXXIX, 307, note (1913). At the same time, characters such as sulcation, plication, areolation and features connected with the beak, according to Dr. M. R. Sahni, are apt to be adversely affected by burning.

Rhynchonella	(*Burmirhynchia*)[6]	*depressa* Buckm.,	
,,	,,	*touchei* Buckm.,	
,,	,,	*hpalaiensis* Buckm.,	
,,	,,	*shanensis* Buckm.,	
,,	,,	*hsenwiensis* Buckm.,	
,,	,,	*hsipawensis* Buckm.,	
,,	,,	*orientalis* Buckm.,	
,,	,,	*obesa* Buckm.,	
,,	,,	*subglobosa* Buckm.,	
,,	,,	*costata* Buckm.,	
,,	,,	*subcostata* Buckm.,	
,,	,,	*pinguis* Buckm.,	
,,	,,	*dattai* Buckm.,	
,,	,,	*ovalis* Buckm.,	
,,	,,	*subovalis* Buckm.,	
,,	,,	*guttula* Buckm.,	Having a general resemblance to the European *R. hopkinsis* Dav.; *R. globulus* is also close to *R. leedsi* Walk.
,,	,,	*gutta* Buckm.,	
,,	,,	*globulus* Buckm.,	
,,	,,	*pyriformis* Buckm.,	
,,	,,	*senilis* Buckm.,	

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[1] Unfortunately Mr. La Touche's collection of lamellibranchs from the Namyaus was lost in transit to Europe. A large collection has since been made by Dr. M. R. Sahni and will shortly be described.

[2] Now being examined by Miss Muir-Wood.

[3] A scantier collection from the same locality was at first referred tentatively to the Oxfordian or even Kimmeridgian by Dr. Cowper Reed.

[4] The "*Holcothyris kitchini*" of Stefanini from Somaliland is considered by Sahni as probably a species of *Terebratulina*.

[5] *Pal. Ind.*, New. Ser., vol. III, Mem., 2(1917); *Ibid.* vol. XXX, Mem. 1(1940).

[6] The differences between many of these variously named forms are scarcely worthy of specific distinction.

Rhynchonella	(*Burmirhynchia*)	*inaequalis* Buckm.	cf. *R. asymmetrica* Kitch., Cutch,
,,	,,	*parva* Buckm.,	
,,	,,	*seengensis* Buckm.,	
,,	,,	*namtuensis* Buckm.,	cf. *R. asymmetrica* Kitch. and *R*, *caucasica* Uhl. of the Caucasus Callovian.
,,	,,	*bawgyoensis* Buckm.,	cf. *R. rostrata* Sow.,
,,	,,	*longa* Buckm.,	Considerable likeness to the Alpine *R. marsupium* Winkl.
,,	,,	*irregularis* Buckm.,	
,,	,,	*pangwolengensis* Buckm.,	
,,	,,	*nammaensis* Buckm.,	
,,	,,	*regularis* Buckm.,	Very like the European *R* *concinna.*
,,	,,	*elegans* Buckm.,	
,,	,,	*rotunda* Buckm.,	Much resemblance to *R. leedsi* Walk.
,,	,,	*transversalis* Buckm.,	
,,	,,	*lenglawngensis* Buckm.,	
,,	,,	*namyauensis* Buckm.,	
,,	,,	*pilgrimi* Buckm.,	
,,	,,	*fluminalis* Buckm.,	
,,	,,	*asiatica* Buckm.,	
,,	,,	*subtrigonalis* Buckm.,	
,,	,,	*nahsaiensis* Buckm.,	
,,	(*Sphenorhynchia?*)	*subplicata* Buckm.,	Much like *R. asymmetrico* Kitch.
,,	,,	*tatiensis* Buckm.,	
Terebratula	(*Holeothyris*)	*sulcata* Buckm.,	
		cooperi Sahni,,	
		concava Buckm.,	
		excavata Buckm.,	
,,	,,	*trigonalis* Buckm.,	
,,	,,	*rostrata* Buckm.,	
,,	,,	*delta* Buckm.,	
,,	,,	*acuminata* Buckm.,	
,,	,,	*angulata* Buckm.,	
,,	,,	,, , var. *areolata* Sahni,	
,,	,,	*subangulata* Buckm.,	
,,	,,	*subovalis* Buckm.,	
,,	,,	*plecta* Buckm.,	
,,	,,	*curvata* Buckm.,	
,,	,,	*macra* Buckm.,	
,,	,,	*elliptica* Buckm.,	
,,	,,	*transversalis* Buckm.,	
,,	,,	*flexa* Buckm.,	
,,	,,	*dubia* Buckm.,	
,,	,,	*orbicularis* Sahni.,	

Dr. Cowper Reed's lists of lamellibranchs from localities on the Lashio-Namtu Road are as follows :[1]

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[1] *Ann. Mag. Nat. Hist.*, Ser., 10, vol., XVIII, pp.1-27 (1936).

[2] Accompanying them were the brachiopods *Terebratula* (*Holcothyris*) *pinguis*, *T.* (*H.*) *subovalis*, *T.* (*H.*) *rostrata*, *Rhynchonella* (*Burmirhynchia*) *shanensis*, *R.* (*B.*) *inaequalis* *R.* (*B.*) *namyauensis*, *R.* (*B.*) *lenglawngensis*, *R.* (*B.*) *ovalis* and *R.* (*B.*) *globulus*.

BATHONIAN HORIZON[2]

Ostraea (*Liostraea*) *davaiacensis* Liss., var. *birmanica* Reed, (The species occurs in the Bathonian of Macon),
,, ,, ,, var. *uncata* Reed.,
,, cf. *calceola* Ziet.,
Exogyra lingulata Walton ?,
Placunopsis cf. *davaiacensis*Liss.,
Gervillia sp.,
Modiola cf. *cuneata* Sow.,
Modiola cf. *lecbenbyi* Lye.,
Nucula cf. *lateralis* Terq. & Jour.,
,, cf. *variabilis* Sow.,
Leda cf. *decorata* Douv.,
Cucullaea personata Reed.,
Arca (*Navicula*) aff. *minuta* Sow.,
,, ,, cf. *aemula* Phill.,
Astarte rustica Walton, var.,
,, cf. *fimbriata* Walt.
,, cf. *pisiformis* Sow.,
,, cf. *robusta* Lyc.,
,, cf. *scytalis* Holdh., var.,
Eomiodon namtuensis Reed,
,, *namyauensis* Reed,
Praeconia cf. *rhomboidalis* (Phill.),
Trigonia cf. *moutierensis* Lyc.,
Eocallista cf. *krenkeli* Cox,
Isocardia cf. *oolithica* Roll,
Mactromya cf. *gibbosa* (Morr. & Lyc.),
Lucina sp.,
Protocardia cf. *grandidieri* (Newt.),
Anisocardia cf. *lycetti* (Roll.),
,, cf. *tenera* (Sow.) ?
Gresslya cf. *concentrica* Ag. ?
Ceratomya cf. *bajociana* (d'Orb.),
Ceromyopsis cf. *rostrata* Douv.,
Cyprina ? cf. *subrotunda* (Morr. & Lyc.),
Thracia cf. *incerta* (Roem.),
Corbula cf. *involuta* Munst.

CORNBRASH HORIZON[1]

Ostraea (*Liostraea*) *davaiacensis* Liss., var. *birmanica* Reed,
,, ,, cf. *dubiensis* Contej.,
Gryphaea eminens (Reed), (A Yunnan form),
,, *balli* Stef.,
,, *lashioensis* Reed,
,, cf. *vinassai* (Diaz Rom.),
,, ? cf. *costellata* (Douv.),

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(1) Accompanying these were the brachiopods, *Terebratula* (*Holcothyris*) *angusta* *T.* (*H.*) *delta*, *T.* (*H.*) *expansa*, *T.* (*H.*) *pinguis*, *T.* (*H.*) *subovalis*, *Rhynchonella* (*Burmirhynchia*) *asiatica*, *R.* (*B.*) *dattai*, *R.* (*B.*) *globulus*, *R.* (*B.*) *irregularis*, *R.* (*B.*) *nammaensis*, *R.* (*B.*) *namtuensis*, *R.* (*B.*) *orientalis*, *R.* (*B.*) *pilgrimi*, *R.* (*B.*) *pinguis*, *R.* (*B.*) *pyriformis*, *R.* (*B.*) *seengensis* and *R.* (*B.*) *subtrigonalis*.

Exogyra multiformis Koch & Dunk.,
,, cf. *monsbeliardensis* Contej.,
,, *bruntrutana* Thurm. (A Yunnan form),
,, cf. *virgula* Sow. (A Yunnan form),
Lopha asellus (Mér.), var. *namtuensis* Reed,
Eligmus cf. *polytypus* Eudes-Desl.,
,, cf. *rollandi* Douv.,
,, cf. *weiri* Cox,
Pecten (*Camptochlamys*) *luchiangensis* Reed. (A Yunnan form),
,, (*Camptonectes*) *lens* Sow., (Also found in Yunnan),
,, ,, *laminatus* Sow,
,, ,, cf. *arcuatus* Sow,
,, ,, cf. *browni* Cox ?
,, (*Chlamys*) cf. *curvivarians* Dietr.?
Lima (*Plagiostoma*) cf. *cardiiformis* Sow.,
Pteroperna decorata Reed,
Modiola cf. *imbricata* Sow.,
,, cf. *angustissima* Newt.,
Tancredia cf. *mactraeoides* Lyc.,
Astarte cf. *scytalis* Holdh.,
Ceratomya concentrica (Sow.),
,, cf. *excentrica* (Roem.),
,, cf. *wimmisensis* (Gill.),
Pseudotrapezium cf. *caudatum* Lyc.

The unreliability of brachiopods as zone fossils is notorious and the facts that every single Namyau form was a new species and that nearly all of them were assigned to two new sub-genera detracted still more from their zonal value. *Holcothyris* has not been found so far outside the Sino-Burmese region[1]. All the lamellibranchs indicate that the two horizons exposed on the Lashio-Namtu road may belong, one of them to any part of the Bathonian and the other to the Cornbrash. There is, therefore, a measure of unanimity regarding the age of the Shan States fossil bands whose content happens so far to have been determined, but, until we can be more certain as to the precise stratigraphical level at which the various bands occur within the series all that can be concluded is that the Namyau series strides a wide sequence including, according to the two palaeontologists who have examined the fossils, the Bathonian, more especially the Cornbrash. The beds may range downwards into the upper Trias, as certain fossiliferous horizons in Indo-China are thought to do. The suggestion that the upper portion ranges into the Cretaceous is probably an exaggeration. Coggin Brown remarks that we may perhaps be dealing with a succession of deposits, generally unfossiliferous and mainly of detrital, lagoonal and subcontinental types, ranging over the Triassic and Jurassic periods[2].

NORTH HSENWI STATE.

North of the Nam Tu river the Namyau beds lithologically like the bed to the south, have been traced by Dr. M. R. Sahni, for an interrupted length of over 50 miles into North Hsenwi where they consist dominantly of fine to coarse grained, purple or pepper-and-salt sandstones with occasional beds of shale and a number of limestone bands. The dip is high and the general strike both of the rocks and of their boundary with the Plateau Limestone is N.E.-S.W. The Namyau sandstones are invariably unfossiliferous, the shales contain but a few indeterminable fragments of lamellibranchs, but in the limestones, which are argillaceous in character, fossils are numerous, the commonest belonging to the genera, *Holcothyris* and *Burmirhynchia*[1]. The following determinations, some of them provisional, have been made[2] :

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[1] M. R. Sahni. *Rec.*, 71, 218 (1936).
[2] *Rec.*, 71, 204, (1936).

Cererithyris ovalis Buckm.,
Holcothyris subovalis Buckm.,
  ,, *macra* Buckm.,
  ,, *angulata* Buckm., var. *depressa* Sahni,
  ,, *subangulata* Buckm.,
  ,, *subcurvata* Sahni,
  ,, *elliptica* Buckm.,
  ,, *excavata* Buckm.,
  ,, *perplicata* Sahni,
  ,, *acuminata* Buckm.,
  ,, *luchiangensis* Reed, var. *minor* Sahni,
  ,, *ovata* Sahni.
  ,, *trigonalis* Buckm.,
  ,, ,, ,, var. *pulchra* Sahni,
  ,, *transversalis* Buckm.,
  ,, (?) *rotunda* Sahni,
  ,, (?) *ovoides* Sahni.
  ,, (?) *micromorpha* Sahni,
  ,, (?) *raoi* Sahni,
Burmirhynchia depressa Buckm.,
  ,, *irregularis* Buckm.,
  ,, *transversalis* Buckm.,
  ,, *regularis* Buckm.,
  ,, *pinguis* Buckm.,
Pecten (*Syncyclonema*) *luchiangensis* Reed,
  ,, sp. nov.,
Modiola sp. nov.,
Patella sp. nov.,
Alectryonia sp.,
Ostraea sp.,
Thracia sp.,
Cardium sp.,
Protocardium sp.

With regard to the age of these beds, there appear to be two separate horizons. From Loi-lem, a locality which has yielded no terebratulids, the rhynchonellids indicate an age near the Bradfordian (Middle Bathonian), while the terebratulids from Hsai Hkao point to an horizon near the Cornbrash (Upper Bathonian).

Prolific lamellibranch faunas have been found at two additional localities, including species of *Leda, Nucula, Mytilus, Crassatellites, Astarte, Thracia, Pecten, Ostraea* and *Lima*; at Kongnim these fossils are associated with *Burmirhynchia namtuensis* Buckm., *B. irregularis* Buckm., *B. senelis* Buckm., *B. shanensis*

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[1] Gen. Rep. *Rec.*, LXVI, 96-97 (1932) ; *Ibid.*, LXVII, 46 (1933).

[2] J. Coggin Brown. *Rec.*, LXXI, 183—184 (1936) ; Gen. Rep. *Rec.*, LXV, 88 (1931); M. R. Sahni. *Pal. Ind.*, New Ser., Vol. XXX, Mem. 1 (1940).

Buckm., *B. hpalaiensis* Buckm., *B. namyauensis* Buckm., *B. depressa* Buckm., *Holcothyris cooperi* Sahni., *H. concava* Buckm., *H. concava*, var. *subexpansa* Sahni., *H. flexa* Buckm., *H. excavata* Buckm., *H. depressa* Sahni., *H. luchiangensis* Reed., *H.*(?) *rotunda*, var. *pyriformis* Sahni, some of them new species.[1]

As Dr. M.R. Sahni has pointed out[2] the Pachham beds of Cutch are related through the genera, *Kutchithyris*, *Flabellothyris*, *Cryptorhynchia* and *Kutchirhynchia*[3] with the Bathonian of Europe in which species of *Burmirhynchia* are found; in this way we have an indirect correlation between the Pachham and Namyau beds. As already mentioned species of *Burmirhynchia* have been found at Shekh Budin in the trans-Indus Salt Range, in beds believed to be Jurassic; the genus is also known in the Callovian of Arabia and Somaliland, and in the Bathonian of trans-Jordania.[4]

THE LOI-AN SERIES AND KALAW RED BEDS OF THE SOUTHERN SHAN STATES.

In the Southern Shan States a succession of red sediments, mostly of an arenaceous character, and including more than one conglomerate of considerable coarseness and thickness, was recognised by Middlemiss under the provisional term of the "Purple Sandstone Zone", and may embrace some portion of the Namyau series of the Northern Shan States. As in the north, broad bands of these rocks have been let down into the Plateau Limestone by faults. There is little doubt that Mr. Middlemiss' "Purple Sandstone Zone" also included some coal-bearing beds of a facies reminiscent of parts of the Upper Gondwana, though deposited outside the confines of the Gondwana continent and belonging geographically to the Angara peninsula, Cathaysia.

Recent work by Coggin Brown and Sondhi has shown that two formations are present, a lower known as the Loi-an series, and an upper known as the Kalaw Red Beds. The so-called ammonites which were supposed to establish the Cretaceous age of the latter are not fossils at all but concretions. Both these series occupy inaccessible and almost uninhabited country to the north and south of the hill-station of Kalaw, forming a belt to the west of the Shan Plateau proper where it begins to break up into long narrow hill ranges separated by deep defiles.[5]

The Loi-an series, named after the coalfield three miles east of Kalaw, is exposed in folds of a more or less isoclinal nature, tucked into the Plateau limestones, which here belong to the dolomitic type, along lines and axes of reversed folds and faults.[6] The general strike of the beds in the neighbourhood of Kalaw is N.N.W.-S.S.E. and their outcrops, with intervening bands and wedges of Plateau limestone have been traced from the edge of the Shan plateau down the Panlaung valley in the Meiktila district S.S.E. 'wards beyond Loi-an to the vicinity of Inwun. An outlier of unknown size occurs some fifteen or sixteen miles north-east of Taung-gyi. The Kalaw beds lie unconformably upon the Loi-an, and the latter have been affected by earth movements which have not disturbed the Kalaw beds.

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[1] Gen. Rep. *Rec.*, LXVIII, 21 (1934); *Pal. Ind.*, New Ser., vol. XXX, Mem., 1 (1940).

[2] *Rec.*, LXXI, 220 (1936).

[3] *Kutchirhynchia* also occurs in the basal Chari beds of Cutch, immediately above the Pachhams, an horizon correlated with the top of the Bathonian.

[4] H. M. Muir-Wood. *Pal. Ind.*, New Ser., vol. XX, No. 6, 28 (1937).

[5] J. Coggin Brown & V. P. Sondhi. *Rec.*, LXVII, 199 (1933).

[6] Gen. Rep. 1899-1900, 143.

The Loi-an series consists of pepper-and-salt or buff-coloured sandstones with hard clay or shale partings, thin bands of bluish-grey argillaceous limestones, and pockets, streaks and lenticles of crushed, friable coal. The coal is confined approximately to one horizon ; some of the seams, though limited in extent, are of good quality but the high dip and prevalent faulting and contortion detract seriously from its value as a fuel.[1] The shales may be buff-coloured or carbonaceous ; some are hard and fine in grain, others are splintery and crumble to powder under the effect of denudation. Some of the bands of limestone, which is very difficult to distinguish from certain types of the Plateau Limestone so intimately associated with the series, are comparatively persistent. In the north the prevailing rock is a light coloured quartzitic sandstone of varying texture which on weathering yields a sandy lateritic soil with pisolites of iron ore. Some of the shales contain some tiny *Estheria* as well as impressions and casts of a small unidentifiable brachiopod, while some of the thin bands of limestone are crowded with fragments of *Alectryonia* sp. and crinoid stems. Northwards, in the Legaung ridge, the bulk of the series is made up of coarse, quartzitic sandstones, with intercalations of mudstone and shale. Among the latter are irregular seams of powdery coal with plant remains ; the *Alectryonia* limestone is also recorded here.[2]

The coal measures of the Loi-an outlier have been divided by Dr. Cotter into three zones :

c. Zone of coal seams, with plant remains.
b. Sandstone zone, with traces of fossil plants.
a. Shaly zone.

From the roofs of the coal seams was collected a flora whose examination has not yet been completed but which includes the following :

Coniferales
  Brachyphyllum sp.
  Pagiophyllum burmense Sahni,
  Cupressinocladus (*Thuites*) *walkeri* Sahni,
    ,, *burmensis* Sahni,
  Conites sp.,
  Masculostrobus sp

This assemblage, identified by Professor B. Sahni[3] is labelled Rhaetic or Jurassic. So far it shows no obvious affinity with any of the known Indian Upper Gondwana floras, and may prove to have closer relationships with the contemporaneous flora of China.[4] This suggestion is interesting in that its substantiation would confirm the conclusion that the Loi-an area belonged to the Angara and not to the Gondwana continent. Coal of a similar nature to that of Loi-an is known in Tonkin, but the flora therefrom has been referred by Zeiller to the Rhaetic and by the French Geological Service of Indo-China to the Noric ; whatever its precise age may be, not a single species can be identified with a Gondwana species. A specimen of fossil coniferous wood from the Loi-an beds, half-a-mile east of Loi-an railway station, has been named *Mesembrioxylon shanense* by Prof. B. Sahni.[1] The coal measures found by Coggin Brown in central Yunnan are unconformably overlain by a great thickness of Red Beds and have yielded a flora related to that of Tonkin. At Phong Saly in Upper Laos a series of shales and sandy shales with abundant plant remains is seen lying below red shales and sandstones; these plant-bearing shales are believed to correspond to the lower of the two groups into which the Tonkin flora (Hongay) has been divided.

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[1] Gen. Rep. *Rec.*, LV, 15 (1923).

[2] Gen. Rep. *Rec.*, LXVI, 102 (1932).

[3] *Pal. Ind.*, New Ser., vol. XI, 98-99 (1931).

[4] *Ibid.*, p. 116, 119, (1931).

In some places, especially in the Mwedaw hills and the Wetpyuye area north of Kalaw, the Loi-an rocks have been altered and mineralised by the intrusions of dolerite. Associated with the porphyry or granite intrusion is the silicification which has affected the neighbouring rocks and may have been responsible for the gold and copper ore present in the limestones ; the latter have been either completely silicified with an accompanying development of wollastonite, or have been marmorised, sometimes to a very pure form of marble.

Of the Kalaw Red Beds the most remarkable are the conglomerates, which are the predominant type of the formation and are well exposed in the road along the Taungwindwin valley. These are of varying texture, composition and compactness, and occur at different horizons.[2] As examples, the band of conglomerate forming the narrow, sharp ridge along the east side of the valley, is of coarse texture, containing large boulders of hard, purple sandstone and smaller ones of limestone derived to some extent at least from the Plateau Limestone, all of them embedded in a red, sandy, calcareous matrix; on the west side of the valley is a high rugged range, built up for the most part by a soft conglomerate remarkable for the large size and angularity of its sandstone boulders and the low proportion of its calcareous contents. Through the solution of the latter, the Kalaw conglomerate bands are occasionally invaded by caves. The sandstones and shales are of a purplish red colour, very soft and friable, and often show a gentle puckering.[3] In the more northerly of the three outliers the beds include a thin band of limestone. In this outlier also the beds are intruded by a coarse pinkish porphyry with kaolinised felspar phenocrysts sometimes half-an-inch in length, and a holocrystalline groundmass composed mainly of laths of the same mineral ; this rock is itself intruded by a fresh, dark dolerite in which the predominant phenocrysts consist of augite, with minor crystals of felspar and hornblende, all of them with almost perfect crystal outlines and set in a groundmass composed of the same minerals with an appreciable amount of devitrified glass. In places a similar dolerite is seen intruding the Plateau Limestone.

The Red Beds of Kalaw were thought by Cotter to be considerably younger than the Loi-an beds. The type exposure of the former occupies a long narrow N.N.W.-S.S.E. synclinal basin carrying the town of Kalaw and part of the road from that hill station to Thazi, and flanked on both sides by the Loi-an series. Farther north are two smaller outliers which at one time no doubt formed a continuous outcrop with the first. The more northerly of these, lying almost entirely upon the Plateau Limestone, occupies the greater part of the Panlaung valley between the high ranges known as Myindaung and Myinbondaung. The only essential difference between the Kalaws and the Namyaus is that the latter include bands of limestone, some of them fossil-bearing.

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[1] *Rec.*, LXXI, 380-388 (1937).

[2] J. Coggin Brown & V. P. Sondhi. *Rec.*, LXVII, 194 (1933).

[3] C. S. Fox. *Rec.*, LXIII, 183 (1930).

The Kalaw Red Beds stretch far to the south of Kalaw. In this direction the conglomerate takes the form of a limestone conglomerate which, according to Middlemiss, has the appearance of having been formed by the disintegration of the much brecciated Plateau Limestone and the flinging down of the weathered fragments as scree-material among the sediments which were in process of forming the purple sandstones. Grotesque pinnacles and "stacks" of this conglomerate are well seen in the rugged, jungly country E. N. E. of Nanpale.[1]

Both these formations have been recognised by A. B. Dutt further north in Yengan State, overlying the Plateau Limestone. Here the Coal Measures consist mainly of shales, sandstones, conglomerates and quartzites, with occasional bands of shaly sandstone, coarse felspathic sandstone and limestone.[2] These beds have a general strike of N.N.W.-S.S.E. and a dip usually between 60° and 70°. With the Plateau Limestone the contact is invariably highly calcified and often obscure ; at their junction with the granite of the neighbourhood the sandstones have been metamorphosed to quartzites. The small outcrop of Red Beds includes soft sandstones, brick-red to purplish in colour and sometimes mottled.

Red sandstones and associated rocks akin to the Namyau beds have been found by Coggin Brown and Sondhi lying unconformably upon the Plateau Limestone between Wan Pong and Kongsong, about latitude 21° N., and characteristically dissected into an intricate network of small, steep-sided valleys and ridges, covered with thick forest.

A little farther east, just beyond Hsaimong, a fossillferous formation of unknown Mesozoic age intervenes between the Plateau Limestone and a further exposure of the Red Beds seen on the western side of the Nam Pang, a tributary of the Salween. Whether this fossiliferous series is equivalent to the Napeng, or to some other horizon of the Jurassic, or to the Trias, it remains to be seen when the few fossils collected have been carefully examined. The beds consist largely of shales which in the lower horizons are very argillaceous and yellowish brown in colour, but give place to sandy varieties, and to limestones and sandstones in the higher levels of the formation. The basal shales have yielded a few minute phyllopods believed to be *Estheria*. The shales vary in colour, and include red, pale olive green, black, grey and bleached varieties, some containing small fragments of fossil leaves and woody fibre. Bands of limestone conglomerate are described, containing small, rounded sandstone pebbles, and passing into tough, impure limestone.[3] The limestones are usually massive and light grey with bands of a somewhat darker colour ; in them structures like calcareous algae have been noted. The purple or pepper-and-salt sandstones are cleaved, broken and much weathered.

Eastwards these beds are overlain by Red Beds, the basal members of which are coarse conglomerates containing rounded pebbles of limestone and of red and olive shale. The conglomerates, which have developed a false stratification due to compression, are highly silicified, both matrix and pebbles alike being cut by thin veinlets of silica. Above the conglomerates come Red beds of the usual type, including very friable, twisted, bleached and blotched purple sandstones, and red or olive sandy shales but no calcareous horizons ; these beds are identical lithologically with the Namyau strata and, like them, begin with a basal conglomerate.

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[1] Gen. Rep. 1899-1900, 146.

[2] Gen. Rep. *Rec.*, 73, 69 (1938).

[3] J. Coggin Brown & V. P. Sondhi. *Rec.*, LXVII. 152 (1933).

On the other side, *i.e.* to the east, of the Nam Pang, a thin belt of mudstones and shales recalls the lower of the above two formations. East of this follows a band of brecciated Plateau Limestone on the middle of which rests a narrow exposure of the Red Beds in the form of red sandstone, accompanied by the usual change in vegetation and scenery.

Possibly it is these beds which are exposed near Yado in Karenni.[1]

Beyond the Salween, the Kalaw Red Beds have been tentatively recognised by Sondhi in Kengtung, the most easterly of the Southern Shan States. The hills east of the Nam Hut valley are made up of coarse deposits of grit and red sandstone, lying upon granite. The last exposure of these beds, before the Siamese frontier is reached, is recorded near the confluence of the Nam Long and the Nam Hka.[2]

In some parts of southern Shan States the Red Beds are of great thickness and must have covered a considerable area ; elsewhere, however, their deposition appears to have been more or less restricted to isolated valleys and basins in the Plateau Limestone.[3]

THE RED BEDS OF SOUTHERN BURMA.

In this connection may be described certain red beds of Southern Burma though no indications of their age are forthcoming.

In the eastern portion of the Amherst district Cotter records a Red Sandstone series resting unconformably upon the Kamawkala Limestone (Trias) and overlain by the Tertiaries of the Htichara basin. This red formation shares with the limestone the hilly country east of Htichara, and is distinguishable from the rugged pinnacles and castellated profiles of the latter by the rounded contours of its outcrops. In places the limestone projects through the Red Sandstone and the impression produced is that the sculpturing of these protruding crags is due in a large measure to denudation previous to the deposition of the sandstone.[4] The dip of the Red Sandstone rocks may be moderate but is frequently steep or vertical.

The typical and predominant rock of the formation is a pink or brick-red to purple sandstone, of fine to medium grain, and often containing sparsely distributed pebbles ; the latter, which are usually no more than ½ or one inch in diameter, are composed either of pink sandstone or of white quartzite, and are frequently angular or sub-angular. Associated with the red sandstones are sandstones of a buff colour and not unlike the much later Tertiary sandstones, clays varying in colour from grey to cherry-red, and conglomerate bands. The clays sometimes have thin partings of argillaceous limestone, from one to three inches thick, containing traces of fossils, mainly lamellibranchs of which an *Astarte* is one. One of the conglomerates, of which there are several exposures in the Thaungyin river is precisely similar to a conglomerate in the Kalaw beds. It is composed of pebbles or boulders of the Moulmein or the Kamawkala limestone, and pebbles of red sandstone, lying in a matrix of red sandstone. The coarser ingredients of this rock range from small pebbles to boulders one foot across. The derivation of the red sandstone pebbles is not known ; that they cannot in all cases have originated from earlier sediments of the same series is shown by the fact that in one locality the conglomerate is the basal member of the succession and rests directly upon the Kamawkala Limestone. The great density of the jungle, however, makes it difficult to establish the true order of succession in the series.

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[1] Their suggested occurrence to the west and southwest of Mong Pawn (Gen. Rep. 1899-1900, 146) is not cofirmed by Coggin Brown & Sondhi *Rec.*, LXVII, Pl. 5(1933).

[2] Gen. Rep. *Rec.*, LXIX, 59 (1935).

[3] *Rec.*, LXVII. 155 (1933).

[4] G. De P. Cotter *Rec.*, LV, 284 (1923).

In the Mergui district a similar set of Red Beds, showing considerable lateral variation, is recorded, striking N.N.E.-S.S.W., *i.e.*, across the underlying Mergui argillites whose general strike is N.N.W.-S.S.E. The beds have been subdivided by Sethu Rama Rau as follows :

(iv) Purple sandstones, shales and conglomerates,
(iii) Fine-grained, pinkish sandstones and shales, with patches of white clay,
(ii) Calcareous sandstones,
(i) Conglomerates and grits.

The last mentioned is found on the islands of Pataw and Patit, off the coast near Mergui town.[1] The other three subdivisions are exposed in the chain of islands from Canister Rock in the north to Mergui itself. The only organic relics found in the series consist of silicified wood and impressions of partly carbonised wood.[2] The arenaceous members vary from fine-grained, reddish sandstones to coarse grits and conglomerates. A characteristic feature of these rocks is the presence of fresh felspar, and pebbles of quartz and slate, the two first derived probably from the neighbouring intrusions of granite, and the last from the Mergui rocks. Quarries for the Mergui Port works have exposed many sections of the Red Beds, showing the sandstones and grits resting upon the denuded edges of the Mergui argillites.

REPRESENTATIVES OF THE LOI-AN AND KALAW BEDS IN MEIKTILA AND THE NORTHERN SHAN STATES.

Some 80 miles south of Mandalay, west of the Southern Shan States, Dr. Cotter reports what may be a Rhaetic-Jurassic group in the Meiktila district, in juxtaposition with a gneissose granite, the junction possibly being a fault. These sedimentaries, which are exposed in the vicinity of Pyinyaung railway station, are made up of conglomerates, sandstones and shales, often red or purple in colour, and appear to rest unconformably upon the Plateau limestones which are exposed to the east of the village. The conglomerate, probably the basal member of the succession, is built up of large boulders, including limestone boulders, and is seen along the junction with the Plateau Limestone.[3] Near the railway station there are traces of unidentifiable fossil plants while two miles north of the village unidentifiable marine fossils include one of the Ostraeidae as the chief form. Dr. Cotter equates these beds with the Coal Measures (Loi-an series) and Red Beds of the Kalaw area to the southeast.

On both sides of the Salween river in Mang Lön, one of the Northern Shan States, Mr. Sondhi has found the Red Beds, which are well developed in the valley of the Mengma, extending up to the head thereof; here the basal bed is a hard grit and arkose.[1] A large basin of these rocks, comprising deep red, sandy shales and sandstones, with the same base of grit and arkose, occupies the Mong-hsaw valley. The basal bed forms the crest of the ridge which bounds the valley on the east. The Red Beds, which here form an asymmetric syncline, overlap the Chaung Magyi phyllites on to the Plateau Limestone in places. Another small basin of the Red Beds occurs at Nah-pan.

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[1] *Mem.*, LV, 19 (1933).

[2] Dudley Stamp. *Q.J. Geol. Min. & Met. Soc. Ind.*, vol. 1, No. 1, p. 20 (1928).

[3] Gen. Rep. *Rec.*, LVIII, 43 (1925).

YUNNAN.

Northeastwards the Namyau beds have been recognised by Dr. Coggin Brown who collected fossils from two miles below Liu-wun, a village in Yunnan, on the Salween river, on the Luchiang-Fangmachang route. The fossil rock, a dark greenish-grey, earthy limestone, with irregular fracture and crowded with fossils, is accompanied by doleritic and andesitic traps, some of which are amygdular, hard, red, shaly tuffs grading into calcareous tuffs, calcareous shales with brachiopod remains, and reddish sandstones.[2] Genera and species are few and specimens of *Rhynchonella* most abundant; the following have been identified by Cowper Reed[3]:

BRACHIOPODA—

Rhynchonella (*Burmirhynchia*) *praestans* Reed, (Closely similar to the typical Namyau form *R.* (*B.*) *costata* Buckm. and to *R. mahei* Mansuy from the Laos.)
,, ,, ,, var. *conjurata* Reed, (The most abundant form.)
,, ,, ,, var. *adjudicata* Reed, (Perhaps identical with the Cutch form, *R. indica* d' Orb.,)
,, ,, ,, var. *tenuiplicata* Reed,
,, ,, ,, var. *discreta* Reed,
,, aff. *cuneiformis* Mans. (Indo-Chinese form).
Terebratula (*Holcothyris*) *ancile* Reed, (cf. *T. ventricosa* Ziet. from the Callovian of Baluchistan and *T.* (*H.*) *angusta* Buckm.)
,, ,, cf. *flexa* Buckm. (from the Namyau beds),
,, ,, *pinguis* var. *luchiangensis* Reed
,, ,, ,, var. *olivaeformis* Reed (type a Namyau form).
,, ,, ,, var. *longisulcata* Reed
,, ,, cf. *subovalis* Buckm.,
,, (*Loboidothyris* ?) cf. *peroralis* Sow., (A Somaliland form.)

LAMELLIBRANCHIATA—

Exogyra bruntrutana Thurm., (Abyssinia and East Africa
,, *eminens* Reed.,
,, cf. *dubiensis* Contej., (A French Sequanian form.)
Pecten (*Syncyclonema*) *luchiangensis* Reed.,
,, (*Camptonectes*) *lens* Sow.,
Lima (*Radula*) aff. *monsbeliardensis* Contej., (A French Sequanian form.)
Modiola ? sp.,
Cucullaea (*Parallelodon*) cf. *cucullata* Goldf.,
,, ,, aff. *virgata* Sow., (A Cutch form.)
Arca aff. *thurmanni* Contej., (A French Sequanian form.)
Nucula aff. *menkei* Roem.,
Ostraea obscura Sow.

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[1] Gen. Rep. *Rec.*, LXXIII, 72 (1938).
[2] J. Coggin Brown *Rec.*, XLVII, 233 (1916).
[3] *Pal. Ind.*, New Ser., Vol. X, Mem. 1, 254, (1927).

Transitional varieties of the rhynchonellids make classification difficult. The similarity of the brachiopod fauna with that of the Namyau beds of the Northern Shan States is striking ; though some of the fossils show a relationship to the Oxfordian or Kimmeridgian (Sequanian), the beds are, like the Namyaus, probably nearer to the Cornbrash.[1]

AGE OF THE RED BEDS OF SOUTHEASTERN ASIA.

The question of the age of the Napeng and Namyau beds, and of beds with similar faunas found in various parts of southeastern Asia has been critically considered by M. Fromaget[2] who would place them tentatively in the Noric. In the Brachiopod Limestones of Luang Prabang in Indo-China the common rhynchonellids are allied to Namyau forms ; *Rhynchonella pseudopleurodon* Mansuy, for instance, resembles *Burmirhynchia costata* Buckm. and *B. subcostata* Buckm., while *Rhynchonella mahei* Mansuy is related to *Burmirhynchia orientalis* Buckm. Other brachiopods from the Luang Prabang fauna are close to Triassic or Rhaetic forms ; *Spiriferina acuta* Mansuy is comparable with *S. shalshalensis* Bittn. from the Himalayan Carnic, and *Terebratula brevirostris* Mansuy greatly resembles *T. pyriformis* Suess from the Carpathian Rhaetic. A fragment of a skull of *Dicynodon* is also in favour of a Triassic age.[3] Included in the Luang Prabang fauna at the same time are the Triassic ammonites, *Discophyllites Tibetites* and *Arcestes,* as well as a *Nautilus* allied to *Clydonautilus, griesbachi* Mojs., one of the zone fossils of the lower part of the Himalayan Noric *Tibetites* and its sub-genera occur in the same late Triassic stage of the Himalaya, while *Arcestes* is found not only in both the Carnic and Noric of the Himalaya but also in the Anthracolithic of the Salt Range. Some of the lignite deposits in these red beds have yielded plants of probably Liassic age.[4]

From a similar fauna at Ban 0, another Indo-Chinese locality, *Holcothyris laosensis* Mansuy shows close affinities with the Namyau species, *H. angusta* Buckm.

Of the Liu-wun fossils, *Burmirhynchia praestans* Reed and its six varieties all show an external resemblance to *Rhynchonella mahei* Mans. from Luang Prabang. The doubtful *Cryptorhynchia* sp. from Liu-wun is said to be very close to *Rhynchonella cuneiformis* Mans. from Pac Ma, another locality in Indo-China. Lastly *Holcothyris ancile* Reed from the Liu-wun beds is described as being very near to *H. laosensis* Mans. from Ban 0. According to Credner[5] the Red Beds of Yunnan can be divided into two discordant series, an older, of Mesozoic age, which has suffered folding, and a younger undisturbed series of Tertiary age[6]. The subject has been dealt with at length and with impartiality by Dr. Coggin Brown.[7] This paper has been supplemented by Dr. M. R. Sahni who emphasises the differences between the Namyau fauna and both that of Luang Prabang and that of Ban 0 and Pac Ma, and agrees with Mr. Buckman and Dr. Cowper Reed that the Burmese fauna belongs to the Bathonian.[1] The latest information on the subject of the Red Beds of this part of Asia will be found in a further paper by Dr. Coggin Brown.[2]

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[1] See *Ann. Mag. Nat. Hist.*, Ser. 10, vol. XVIII, p. 2 (1936).

[2] *Bull. Serv. géol. Indo-Chine.* vol. XVIII, fasc. 5 (1929).

[3] *Ibid*, XII, fasc. II (1923).

[4] Bertil Hogböm *Bull. Geol. Inst. Univ. Upsala*, XII, 107-108 (1913) ; Zeiller. "Flore fossile des conches de charbon du Tonkin"),

[5] Yunnan Reise des Geographischen Instituts der Sun Yatsen Universitat (1930), II, p. 52.

[6] *Rec.*, LXVII, 198 (1933).

[7] *Rec.*, LXXI, 170-216 (1936).

According to Dr. A. W. Grabau, the well-known Red Beds of western China (S'su-chuan) are of Lower Cretaceous age. In southern Persia and the adjoining parts of Baluchistan there is a similar coloured series, almost incapable of reduction to any recognisable sequence and covering the period from the Lower Lias, certainly to the Middle and probably to the Upper Cretaceous ; volcanic activity was rife throughout and many of the lavas appear to be submarine.

It seems unnecessary to conclude from the above comparisons that all the faunas belong to the same stratigraphical stage. Vast tracts in western China, Indo-China and Siam as well as in the Shan States, are covered by Red Beds of Mesozoic age. It is suggested that in southeast Asia we have a thick geological series or system, ranging from the Upper Trias into the Jurassic and represented by scattered fragments of various thicknesses and belonging to different parts of the vertical section. The faunas at Luang Prabang, Ban 0, Pac Ma, Muong The and other localities we may assume to belong to a low horizon in this Noric-Jurassic system, a horizon corresponding to the Noric stage. The assemblages at Napeng and Con Tagne occur higher up in this system and bear strong evidence of a Rhaetic age in spite of the presence of survivals from older faunas. Of the two fossil horizons in the Burmese Namyau beds, both have been assigned to the Bathonian, one of them, like the Liu-wun beds, corresponding probably to the Cornbrash. The Namyau is a very thick formation and a large section of it is unfossiliferous. It is quite likely, therefore, that it may extend vertically for some distance either below or above its own fossiliferous horizons, or possibly in both these directions. In this way the beds at Napeng may be a facies of an unfossiliferous part of the Namyaus ; in other words they, and possibly also the beds in Indo-China having the same general family resemblance, may be nothing more than synchronous lateral variations of lower portions of the Namyau formation. The basal rock of both the Napengs and Namyaus is a conglomerate containing pebbles of the Plateau Limestone as well as of older rocks. The suggestion put forward above may be represented diagramatically as follows :—

		Unfossiliferous Namyau beds.	
Liu-wun beds.		Namyau fossil bed B.	Kalaw Red Beds. ?
		Namyau fossil bed A.	
Con Tagne beds.	Beds at Napg.	Unfossiliferous Namyau beds.	Loi-an Coal measures.
Muong The beds, Luang Prabang beds, etc.		?	

Palaeogeography.—During the Jurassic period, the face of Asia changed considerably, and the penetration of the Gondwana continent by encroaching arms of the sea which had commenced in the Triassic period became much more marked.

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[1] *Rec.*, LXXI, 219 (1936).

[2] *Rec.*, LXXIII, 514 (1939).

Much of this old continent persisted throughout as land, in witness whereof are the Jurassic coalfields of India, South Africa, and Australia, but marine transgression in certain directions, from the Tethys on the north and from the Southern ocean, began in the early part of the period.

Burma formed part of Cathaysia, a landmass of either peninsular or insular character, at the southeastern corner of the Angara continent. According to M. Fromaget[1] this land mass at the beginning of Jurassic times was more or less divided from the main mass of Angaraland by a branching gulf, debouching southwestwards into the sea channel which still separated this continent from Gondwanaland. In parts of this gulf marine faunas from time to time took the place of the Red Bed lagoonal sedimentation which commenced probably in the late Permian and continued into the Tertiary period. During the latest epoch of the Trias such a marine fauna flourished at Luang Prabang, Muong The and elsewhere ; in other parts of this region lagoonal conditions were by that time well established. Later on, perhaps in the Rhaetic epoch, the Napeng and Loi-an fauna took possession of a western branch of the gulf, and still later the lagoonal conditions which then predominated over the Burmese area, were replaced locally at Namyau by shallow sea water with ephemeral and specialised faunas ; this later invasion is thought to have happened once or twice during the Bathonian epoch. These transgressions filled up hollows in the Plateau Limestone of the Shan States with fine muddy silts and produced the coarse beach deposits along the shores. A similar marine invasion has left traces in Malaysia and Sumatra of the peculiar Napeng fauna ; in Timor the Rhaetic is represented by bituminous limestones and dark shales with *Choristoceras* and *Myophoria*.

The sea channel mentioned above seems to have formed a passage of communication between the Asiatic portion of the Tethys and the Southern Ocean, sweeping round through Malaysia, Sumatra, Timor and New Guinea, perhaps up past the Philippine Islands and certainly eastwards round the eastern or Australian end of Gondwanaland. The Mesozoic plants of the Loi-an beds of the Southern Shan States are more closely related to the Chinese flora of that era than they are to Indian Upper Gondwana forms, and both the Chinese and Burmese floras belonged to the Angara continent which covered the greater portion of Asia in Mesozoic times.

In all probability the Tethys extended from northern Burma westwards along the Himalayan region by way of eastern Persia to Europe throughout the Rhaetic epoch. The peculiarity of the Burmese Rhaetic fauna is exaggerated by the absence of any links between it and the faunas of southern and central Europe. Though no trace of Rhaetic fauna has hitherto been discovered in the Kioto or Megalodon Limestone of the Himalaya and Hazara, it is possible not only that the uninterrupted Kioto sequence includes the Rhaetic stage but that the now entirely unfossiliferous layers of the latter originally comprised a fauna whose ingredients have become completely obliterated by subsequent solution. Had a sufficient number of the members of this fauna survived, it might have been possible, in spite of any difference in facies, to find connecting links therein between the Burmese Rhaetic and that of the Mediterranean.

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[1] *Bull. Serv. géol. Indo- Chine.*, XVIII, fasc. 5, opp. p. 16.

That there was uninterrupted deposition from the Triassic to the Cretaceous period in all sections of the Tethys area is not supported by palaeontological evidence, but the conformability of this long sequence is impressive, and the unfossiliferous nature of such a large section of it would partly account for the want of palaeontological continuity. The greater part of this unfossiliferous component consists of limestone which may have been originally as richly fossiliferous as the few horizons which have escaped the destructive effects of compression, solution and recrystallisation. Probably there were intervals of non-deposition, but these appear to have left no trace.

In Liassic times there is evidence that the Tethys stretched eastwards through Asia Minor and Northwest Persia, along the region north of the present main Himalayan chain (as shown by the *blocs exotiques* in Malla Johar), over the trans-Indus Salt Range area, into southern Tibet between the Tsangpo (Upper Brahmaputra) and the Nepal frontier and probably connected southward with the Indian Ocean.

Localised submergence during the Liassic epoch was responsible for an arm of the sea stretching southwards from the Tethys into Baluchistan, and for another arm which extended from the same basin in the same direction through Maghara in the Sinaitic peninsula and central Arabia. One of these two arms continued through Kenya Colony to western Madagascar. Probably both arms in time reached as far uniting round a large island named by Stefanini "Farsia" which covered what are now the Persian Gulf, eastern Arabia, southwest Persia, the island of Socotra and part of Somaliland[1]. These connections are clearly indicated by the close resemblance of the Middle Liassic fauna of Baluchistan and Madagascar with that (Domerian-Toarcian) of southern Europe[2]. In the Liassic epoch the Baluchistan channel covered the trans-Indus Salt Range and remained there at least as late as Callovian times.

The only marine Jurassic rocks in Australia occur at the western end of the continent and contain many species identical with those of the English Lias and Oolite. Such a remarkable close relationship points to free communication between the European part of the Tethys and the Southern Ocean, off a section of the shore of which were accumulated the Western Australian deposits. This intercommunication, it is concluded, was effected *via* the Dutch East Indies where all zones of the Lias are found in Timor and Rotti, while the Upper Lias is present in the Sula Islands, the Obi Islands and Misol[3] and thence round the eastern end of Gondwanaland which embraced all but a small western portion of Australia, through the islands of New Zealand ; the latter possess a marine Jurassic sequence ranging from Lias to Tithonian. In the Lias of Rotti are found the zone fossils of the Middle Lias of Europe, *Dactylioceras commune* and *Arnioceras semicostatum*. The Lias of Indo-China also shows close affinity with that of Europe and possesses several species in common with that region. The Lias of Borneo is assumed to have been deposited on the other side of the large southwardly directed peninsula of Cathaysia which terminated the Angara land-mass to the south-east. This landmass stretched northwards over China to the Arctic Ocean, and from Japan westwards to the Caspian Sea area. On the northeast it was deeply indented by the long

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[1] *Sped. Ital de Filippi* (1913-14), Ser. II, Vol. vi, Fig. 1, p. 17.

[2] *Monogr. Hunt. Mus. Glasgow Univ.*, vol. IV, 66, (1925) ; *Pal. Ind.*, New Ser., vol. X, pt. 2, 815 (1933) ; *Ibid.* XXII, No. 3, 18 (1936).

[3] H. A. Brouwer. "Geology of the Netherland East Indies"., p. 25 (1926).

Ussuri gulf whose waters covered southwestern Japan and opened northwards into the Arctic Sea ; northwestwards it extended through Russia to Spitzbergen and beyond.

The latest marine occupation of Indo-China is calculated to have finished in the Lias, deposits of which occur in southern Annam and Cochin China, marking the position of what are believed to be two straits across the promontory of land. The wide interchange of faunistic elements, which had suffered some degree of suspension as between America and the Himalaya during Noric times, was restored before the end of the Liassic epoch, and is well illustrated by the universal distribution of the genus *Arietites* which is known from Europe, western Asia, India, Timor, California, Nevada, Mexico and South America[1]. From the region north of the Himalaya to the Mediterranean area, not only was there free communication between faunas which show insignificant local peculiarities but, from the Carnic to the Liassic epochs, inclusive, sedimentation was of a nearly uniform lithological character. Eastern Persia, on the other hand, emerged from the Bagocian or Lower Bathonian sea and received coloured sub-aerial deposits with their plant remains[2]; sediments with a similar flora have been identified in Afghanistan[3].

On the whole, marine transgression increased during the middle stages of the Jurassic, and we find in Bathonian times evidence that the Arabian channel had spread over Abyssinia, where the Antato Limestone is closely related to the Indian Pachham beds, and also over Somaliland and many parts of the east coast of Africa. The Bajocian and Bathonian are unknown in Asia Minor, but the Oxfordian has been recognised. The Middle Jurassic of Arabia belongs probably to two horizons, a Bathonian-Callovian which includes the lamellibranch *Arca* (*Parallelodon*) *egertoniana* (Stol.), a species known in Somaliland, Tanganyika and the Spiti Shales of the Himalaya, and a Sequanian. From the Middle Jurassic (Bathonian-Bajocian) in northeast British Somaliland comes a species of *Burmirhynchia* (*B. subversabilis* Weir), two species of the lamellibranch genus *Eligmus*, and several other fossils ; these beds are succeeded by limestones which have yielded fragments of a *Belemnopsis* indistinguishable from *B. tanganensis* Futt., and occupy some part of the sequence Corallian-Kimmeridgian[4].

The invasion of what is now New Guinea began in Upper Bajocian times and continued throughout the Callovian and Oxfordian. The islands of the Dutch East Indies mentioned above remained covered by the sea from the Upper Lias to the end of the Jurassic period.

If the marine fossils found in the Tal series in Garhwal are rightly assigned to the Jurassic, they afford evidence of an encroachment southwards of the Tethys over the northern margin of Gondwanaland now occupied by part of the Lesser Himalaya. This encroachment, which was of very short duration and perhaps restricted to a section of Garhwal, must have taken place at some time during the earlier half of the Jurassic period, since the character of the Spiti Shales is sufficient proof of a definite recession of the sea in a northerly direction during the closing stages of the Jurassic.

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[1] C. Diener, *Mem.*, XXXVI, 315 (1912).

[2] L. R. Cox. *Pal. Ind.*, New Ser., vol. XXII, Nos. 2 & 3 (1936). The floras of both these regions belong to the Angara continent.

[3] L. F. Spath. *Ibid.* Mem. 3 ; *Rec.*, LIII, 59, (1921.)

[4] C. Barrington Brown. *Q. J. G. S.*, LXXXVII, 263 (1931).

That the geographical conditions sketched above persisted in the main throughout the rest of the Jurassic period is shown by the resemblances between the stage faunas of various parts of this extensive mediterranean basin. As examples may be cited the following : (i) the fauna in Kawhia harbour, New Zealand, which is allied to that of the Pachham stage of Cutch ; (ii) the close affinity between the Bathonian of Somaliland and that of southern Arabia, and the resemblances of both with the Mediterranean Bathonian ; (iii) the alliance of the Tithonian of Te Puti in New Zealand to that of the Dutch East Indies; (iv) the close relationship of certain *Macrocephalus* marls in Madagascar (Golden Oolite) to the Chari group of Cutch ; (v) the general intermediate palaeontological position of the Arabian Jurassics with respect to beds of the same age in Syria and in Aden ; (vi) the close resemblance between the Upper Athleta beds and Dhosa Oolite of Cutch, on the one hand, and beds of the same age in Syria ; (vii) the general affinities between the Jurassic of Cutch and that of the Caucasus. There are in the Jurassic 122 cephalopod species common to Cutch and Europe. Of these, 69, chiefly from the Chari series and especially from the Athleta Beds and Dhosa Oolite, occur in middle and western Europe, while 53, from the Katrol and younger stages are found in the Alps and Mediterranean area, where the Upper Jurassic is better known than it is further north.

During the latter part of the Jurassic period, from the Oxfordian to the Tithonian and well into the cretaceous, the Tethys sea reached as far west as the island of Cuba and the States of Mexico and Texas. Of the Tendaguru series in Tanganyika, the *Trigonia smeei* Sandstone contains Portlandian ammonites, but it is followed by fresh-water marls of Purbeck age with saurian remains and traces of a Wealden flora. The Malm of the Southern Andes, corresponding to all but the lowest of the Cutch Jurassic stages, as well as to the Spiti Shales and some of the underlying horizons is characterised by a fauna which is markedly Himalayan, including many of the Spiti genera such as *Spiticeras*, *Blanfordia*, *Virgatosphinctes*, *Berriasella*, *Himalayites* and *Kossmatia* ; according to Uhlig the connection between the Himalaya and South America lay across the southern Pacific[1]. Grabau has suggested that the fauna of the Spiti sea may have been "hedged off from that of southern Europe, probably by a land barrier".

The fauna of the Tethys during most of the Jurassic period seems to have attained a wide degree of homogeneity from central America through Europe and southern Asia to Australia, the more marginal zones of middle Europe showing infiltrations from the Boreal province which lay to the north of Angaraland and of the other continental mass which embraced Scandinavia, Iceland, Greenland and most of North America. Traces of such Boreal infiltrations are extremely few in the Indian region of the Tethys ; in the Himalayan faunas, for instance, a species of *Aucella* (*A. spitiensis*) is the only form which can be regarded as such an exotic[2].

The presence of marine Jurassic beds among the Upper Gondwana sediments of the east coast of India is extremely doubtful. Ammonites, which at one time were thought to be closely comparable to the "*Stephanoceras opis*" found in the Chari and Katrol stages of the Cutch Jurassic, are now identified as Lower Cretaceous forms. Whether the east coast of India, therefore, was formed before the end of the Jurassic period is uncertain, unless we can rely upon the Liassic age and marine habit of the crustacean, *Eryon barroviensis*, claimed to have been found near Ongole. The first reliable indications of the presence of the east coast and the Bay of Bengal are seen in the above mentioned marine Cretaceous fossils and will be more fully considered in the following chapter.

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[1] *Denkschr K. Akad. Wiss., Wien.* vol. LXXXV, pp. 598, 608 (1910), ; J. W. Gregory, *Q. J. G. S.*, Vol. LXXXVI, p. xciii (1930).

[2] *Ibid.* p. xcii (1930).

The relationship between the Cutch and Malagassy Jurassic faunas is very close and points to an uninterrupted line of communication, probably along a continuous coast between the two areas. In this way the Indian peninsula and Madagascar lay at the extremities of a strip of Gondwanaland bounded on the west by the large channel which reached from the Mediterranean to South Africa and contained the large island of "Farsia". Whether this strip of land was separated from the rest of the Gondwana continent in Jurassic as it was in Cretaceous times, by another arm of the Tethys to the east, and was thus cut off to form an island similar to but larger than "Farsia", is not certain, though it may well have been so. Before the end of the Jurassic period this island—if the strip of a land existed as such—seems to have been split up into an archipelago. Brazil, Africa and Australia are believed to have remained united during the Jurassic period, but not *via* India.

CHAPTER XXVI.

THE MARINE CRETACEOUS AND SOME EQUIVALENTS.

Distribution. **The East Coast of Southern India.**—Introduction; Position of exposures; Subdivision; **Utatur stage**—Lithological composition and thickness—Coral-reef limestone—Boulder beds—Coastal character—Fauna; **Trichinopoly stage**—Lithological composition—Coastal character—Relationships to older rocks—Thickness and extent—Fauna; **Ariyalur stage**—Extent and composition—Lower and upper boundaries—Mode of accumulation—General Character of the fauna—Subdivision and faunas in the Pondicherry area; **Niniyur and Nerinea Beds. Tanjore. Ariyalur stage in Madras. The "Infra-Trappean" beds of Dudkur, Godavari district. Assam. The Bagh Beds and the Nimar Sandstone**: Distribution; Nimar Sandstone; Bagh Beds; Old Cretaceous peneplain. **Cutch and Kathiawar**: Cutch; Kathiawar. **Rajputana. Baluchistan and Western Sind**: Baluchistan; Sind. **The Sulaiman Range. Southern Waziristan. The Samana Range. Kohat. Tirah. The Salt Range and its Trans-Indus Continuation. Afghanistan**: Distribution; Lower Cretaceous; Upper Cretaceous. **Chinese Turkistan. Eastern Persia. Himalaya**: The Giumal Sandstone; The Chikkim beds; The Flysch. Blocs exotiques. The Tal series. **Hazara. Attock. The Peshawar district; Chitral, Wakhan and Kashmir**: Chitral; The Burzil gorge; The Dras Volcanics; Kargil Gilgit; Wakhan; Lingzi Thang; Chisil Pass; Karakoram Pass. **Tibet**: Southern Tibet. Central Tibet; Southeastern Tibet. **Mount Everest area. Burma**: Pakokku; The Arakan Yoma Cretaceous; The Axial Beds of the southern end of the Arakan Yoma; The Chin Shales of the Minbu Arakan Yoma; The Kanpetlet Schists of Pakokku; Manipur; Ramri Island; the Andaman and Nicobar Islands. Palaeogeography.

Distribution.—Marine Cretaceous deposits are found throughout the Extra-peninsular belt of India, from Cutch and Kathiawar through Sind, Baluchistan, Waziristan, Kohat, Tirah and Rajputana, northwards to the Salt Range, Peshawar, Hazara, Attock, Chitral and Wakhan, and thence southeastwards and eastwards along the northern flank of the Himalaya. They have also been recognised in the Arakan Yoma and other parts of Burma. Marine sediments of this system are also to be found skirting the margin of the Peninsular region along the east or Coromandel coast and in Assam. A condensed sequence of similar beds occurs also in the Narbada valley.

THE EAST COAST OF SOUTHERN INDIA.

Introduction.—The marine portion of the Cretaceous found along the east or Coromandel coast of India belongs mostly to the Upper division of that system, but that the Lower is not unrepresented is known from the recent determinations of the ammonites from the Budavada, Ragavapuram, Vemavaram and Sripermatur beds. On account of their plant remains, all these formations have been described under the heading of Gondwana, to which chapter reference should be made concerning the equally important marine fossils.

Even amongst the Trichinopoly and Pondicherry Cretaceous, with its rich marine faunas now to be described, plant beds are not wanting, though no considerable flora has so far been collected therefrom. Along this coastal area, therefore, Gondwana continental conditions can be traced up into the Upper Cretaceous, though greatly outclassed by marine sedimentation. The encroachment of the

		Europe.	*S. India.*		*Assam.*	*Narbada valley.*	*Cutch and Kathiawar.*	*Rajputana.*	*Baluchistan.*	*Waziristan.*
Upper Cretaceous.	Danian.	Montian.	Niniyur and Nerinea Beds.						Cardita beaumonti Beds.	
		Maestrichtian.	Ariylaur.	Trigonoarca Beds.	Shillong scarp beds.				Olive Shale. Pab Sandstones.	Pab Sandstones.
	Senonian.	Campanian.		Valudayur.		Bagh beds.	Kathiawar Cretaceous.			
		Emscherian.	Trichinopoly.						Hemipneustes Beds.	
		Turonian.								
		Cenomanian.	Utatur.							
Lower Cretaceous.		Albian.								
		Aptian.	Tripati, Pavulur and Sattavedu beds.				Ukra beds of Cutch.	Abur beds.		
	Neocomian.	Barremian.	Ragavapuram, Vemavaram and Sripermatur.							
		Hauterivian.							Lituola Beds. Parh Limestones.	Parh Limestones.
		Valanginian.							Belemnite Beds.	Belemnite Beds.
		Berriasian.							? Conglomerates N. of Quetta.	

Kohat.	*Salt Range.*	*Afghanistan.*		*Hazara and Attock.*	*Chitral and N. Kashmir.*		*Himalaya.*		*Southern Tibet.*	*Burma.*
				Beds at Khurram and Darabwali.	Base of Dras Volcanics.	Karakoram beds.			Stages 7-10 inclusive.	Cardita beaumonti beds of the Arakan Yoma.
		Exogyra Limestone.	Hippuritic Limestone.		Kargil beds.		Chikkim Series.	Flysch.	Third Scarp Limestone. Shaly Limestone. Second scarp Limestone.	Yeshin beds.
		Foraminiferal Limestone.			? Leh beds.				Shales. First Scarp Limestone.	
? Upper Lithographic Limestone. ? Variegated Quartzitic Sandstone. ? Lower Lithographic Limestone.					Beds at Lingzi Thang.				Hemiaster Shales.	Ramri Cretaceous.
									Kampa Shales.	
					Chisil Pass beds.	Prega plain beds.			? Giri Limestone.	
				Giumal Sandstone.	Beds at Lingzi Thang.		Giumal Sandstone.	?Tal Series.		Ma-i beds of Sandoway.
Phosphatic fossil band.		Red Grit Series.				Burzil gorge beds.				Mõng Mit beds.
White Quartzitic Sandstone.	Lumshiwat and other white Sandstones.	Orbitolina Limestone.			Orbitolina Limestone.					Andaman I. Limestones.
		? Red Grit Series.							? Giri Limestone.	
Glauconitic Sandstone.	Belemnite Shales.			Top of the Spiti Shales.			Top of Spiti Shales.			
	Subthurmannia and *Blanfordiceras* horizons.									

sea along this coast was gradual and oscillatory, and there is no single plane of division between Upper Gondwana strata on the one side and marine Cretaceous on the other, the two facies associated in a fashion which complicates a satisfactory classificatory subdivision.

The Mesozoic deposits on the east coast of India owe their preservation to what might almost be described as a fortunate accident. A few miles incursion instead of a few miles regression of the sea, and one of the most critical pages in the Mesozoic history of India would have been lost for ever. The younger Cretaceous deposits of this region range from the uppermost Albian (Vraconnian) to the top of the Danian, and constitute a mainly marine continuation of the partly sub-ærial, partly marine, Upper Gondwanas further north. The survey of these highly interesting Upper Cretaceous remnants was carried out during the '60's and early '70's of the last century, since when no systematic investigations have been undertaken. This stratigraphical work will no doubt stand the test of revision as well as most of the admirable efforts of the old pioneers generally do, but more adequate topographical maps and a general advance in knowledge of Cretaceous deposits in other parts of the globe during the past seventy years are likely to necessitate some changes of view and, in the question of fossil determinations[1], not even excepting the cephalopods which were redetermined in 1898 and 1910, a comprehensive revision is highly desirable.

Position of exposures.—The younger Cretaceous beds of southern India occur in the great plain which extends along the Coromandel coast from north of the Godavari river to Cape Comorin. They rest to the west upon the gneiss or occasionally upon small patches of the Upper Gondwana beds; they have a low easterly dip and are covered on the east by Pleistocene beds known as the Cuddalore Sandstones, and by the alluvium of the sea coast. They are exposed for the most part in three detached areas, separated from each other by the alluvial deposits of the Ponaiyar (southern Penner) and Vellur rivers. The southern and largest of these areas, between the Vellar and Coleroon rivers, is in the Trichinopoly district; of the two smaller exposures, that between the Vellar and Ponnaiyar lies in the district of South Arcot immediately north of the town of Vriddhachalam (Viruddhachalam), while the other is situated a few miles northwest of the French town of Pondicherry. The still smaller occurrences in Tanjore, south of the Coleroon, will be mentioned in the sequel.

The very irregular outcrop in Trichinopoly is about 25 miles in length from north to south and has a maximum width of about the same distance. Its southern boundary is formed largely by gneiss; northwards, it is doubtless continuous beneath the Vellar alluvium with the Vriddhachalam outcrop which measures approximately 15 miles by five, striking N.N.E.-S. S. W. The latter tract, in which only the highest subdivision is exposed in a very few isolated localities, is probably continuous northeastwards beneath the alluvial silts of the Ponnaiyar with the Pondicherry tract which commences near Valudayur and occupies a small area about 12 miles long from northeast to southwest by six miles broad.

These three exposures, therefore, form part of a belt of Cretaceous just under 100 miles long with a dip to the east or southeast, the lowest beds appearing at

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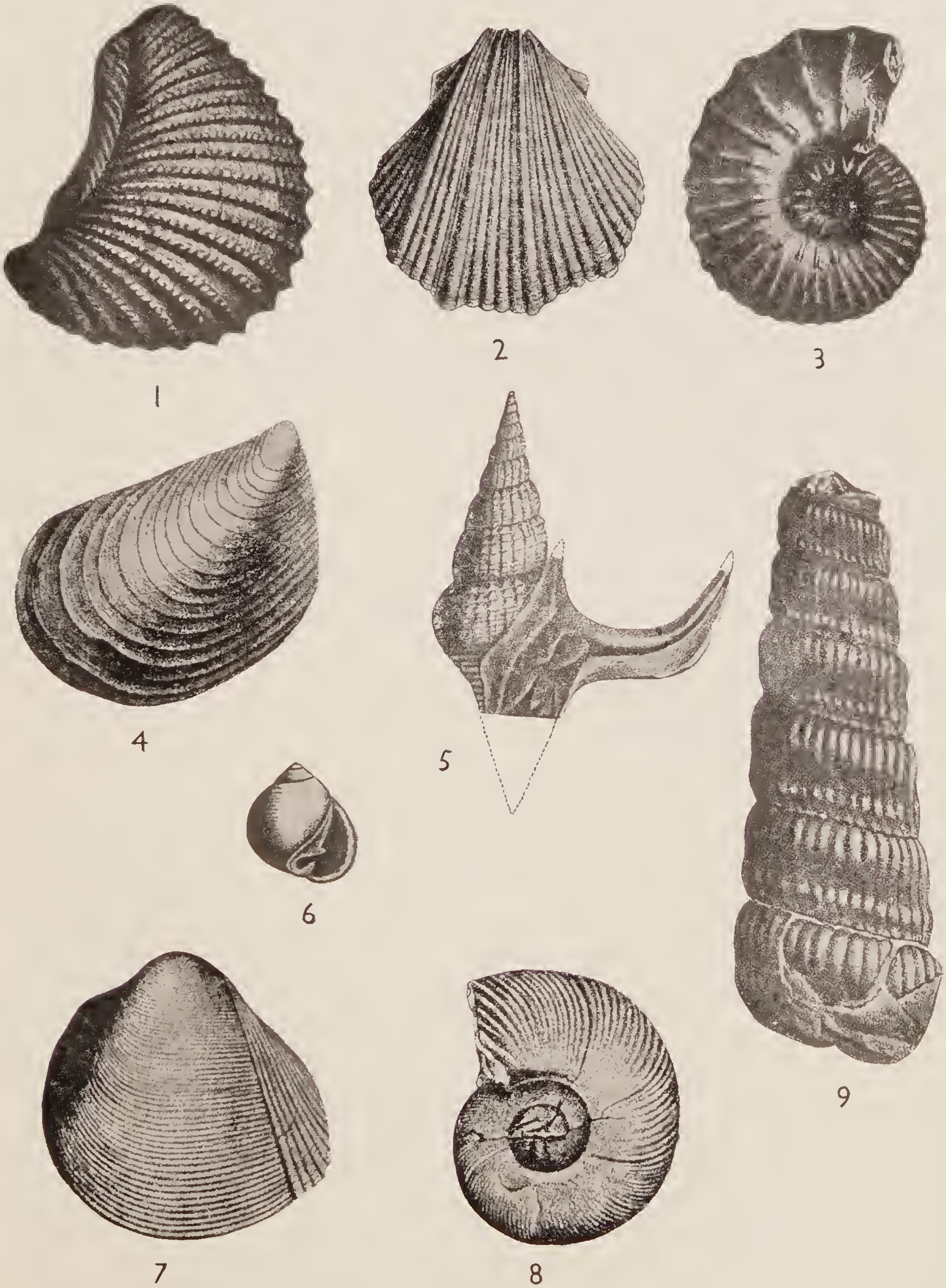
[1] Full list of fossils will be found in the early publications of the *Palæontologia Indica*, Ser. I & III, Vol. I (1861-5) Cephalopoda; Ser. V, Vol. II (1867-8) Gastropoda; Ser. VI, Vol. III (1870-1)—Pelecypoda; Ser. VIII, Vol. IV (1872-3)—Brachiopoda, Ciliopoda, Echinodermata, Anthozoa, Spongiozoa, Foraminifera, Arthrozoa and Spondylozoa.

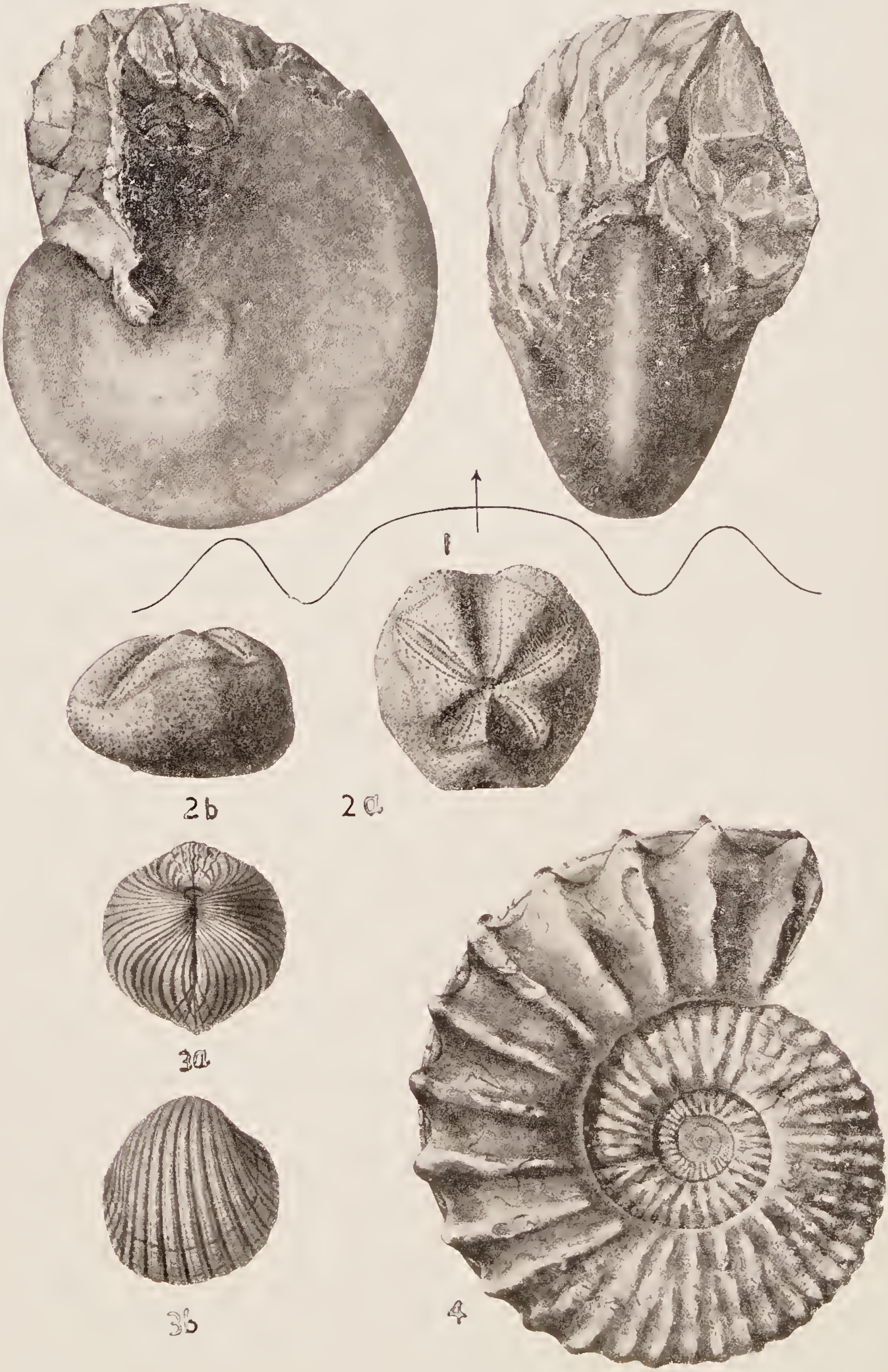


CRETACEOUS FAUNA (A).

1. *Trigonia scabra* Lam. 2. *Pecten quinquecostatus* Sow. 3. *Acanthoceras rhotomagense* (Defr). 4. *Inoceramus simplex* Stol. 5. *Pugnellus securifera* (Forb). 6. *Avellana ampla* Stol. 7. *Protocardium hillanum* Sow. 8. *Desmoceras (Puzosia) planulata* (Sow). 9. *Turrilites costatus* Lam.

G. S. I., Calcutta.

N.B. *For* "5. *Pugnellus securifera* (Forb)" *above, Read Aporrhais securifera* (Forb)



CRETACEOUS FAUNA (B).

1. *Nautilus* (*Hercoglossa*) *danica* Schloth. 2. (a,b). *Hemiaster oldhami* Fourt. 3. (a,b). *Cardita* (*Venericardia*) *beaumonti* d'Arch. & H. 4. *Schloenbachia inflata* Sow.

G. S. I., Calcutta.

the western boundary and the higher succeeding in regular order to the east or southeast. In the Vriddhachalam and Pondicherry areas the rocks are ill exposed and the dip indistinct. Throughout the belt and especially in the southern portion of the Trichinopoly area oblique lamination or current bedding prevails extensively. The western boundary, when not hidden by patches of Cuddalore sandstone, is with the gneiss except along a portion of the line in the Trichinopoly area where a narrow interrupted strip of Upper Gondwanas intervenes. Southwards also the belt ends for the most part against gneiss.[1] To the east and southeast, the rocks dip for the most part beneath the Cuddalore sandstones, the distance of this boundary from the sea varying from 2-4 miles in the north to nearly 45 miles in the south.

Subdivision.--The succession is divisible into four stages, of which the two lower are present only in the large Trichinopoly area at the southern end of the belt; in descending order these stages are:

Trichinopoly area.		*Pondicherry area.*	*Approximate European equivalent.*
Niniyur Beds		Nerinea Beds (F)	Upper Mæstrichtian and Montian.
Ariyalur stage.	Upper, almost unfossiliferous sands.	Trigonoarca Beds (D-E)	Upper Campanian and Lower Mæstrichtian.
	Lower, fossiliferous group.	Valudayur Beds (B, C and the unfossiliferous sands A).	Lower Campanian.
Trichinopoly stage	Upper (Varagur) sub-stage		Emscherian.
	Lower (Garudamangalam) sub-stage.		Bulk of the Turonian.
Utatur stage.	Upper		Upper Cenomanian and lowest Turonian.
	Middle		Middle Cenomanian.
	Lower		Uppermost Albian and Lower Cenomanian.

Until a revision of the ammonites and other fossils in the East Coast Cretaceous has been carried out, it would be unwise to attach too precise a value to the above approximate correlation with the Cretaceous of Europe. There is a general correspondence between the Utatur and the Cenomanian, the Indian stage, however, trespassing upwards probably into the Lower Turonian, and downwards into the Albian, while the Trichinopoly appears to be the equivalent of most of the Turonian *plus* Lower Senonian. The Ariyalurs include the upper part of the Senonian and the lower of the Mæstrichtian, the Niniyur and Nerinea beds ranging perhaps from the middle of the Mæstrichtian to the top of the Montian. Kossmat, from certain ammonite resemblances, placed the highest horizons of the Utaturs in the Lower Turonian, and this assignment is supported by the occurrence in these horizons of *Inoceramus labiatus*. Whatever may be said for or against such a correlation, there seems good reason for supposing that, while the lower portion of the Trichinopoly belongs to the Turonian, its upper portion is rightly referred to the

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[1] Along what has been mapped by Mr. H. F. Blanford as a fault.

Lower Senonian (Emscherian). The Valudayur and Trigonoarca subdivisions of the Ariyalur stage, together with the overlying Niniyur or Nerinea beds. represent the Upper Senonian (Campanian) and Danian (Mæstrichtian and Montian).

UTATUR STAGE.

Lithological Composition and thickness.—The Utatur (Ootatoor) stage named after a large village some distance northeast of Trichinopoly town, is composed chiefly of argillaceous beds. Fine silts, calcareous shales and sandy clays, frequently concretionary and more or less ochreous, prevail throughout the subdivision, and in the southern portion of the area constitute almost the entire bulk of the deposit. From south to north certain changes are noticeable after crossing the parallel of Utatur; in the lower horizons to the west intercalated limestone bands make their appearance, to the great enrichment of the fauna, while in the upper part of the stage to the east the appearance of sands, grits and conglomerates synchronises with a corresponding impoverishment in fossil contents. Conglomerates are of very rare occurrence among the lower beds. Gypsum occurs in most of the argillaceous strata and is to a certain extent characteristic of the group. The dips are often irregular and apparently due to the original deposition of the beds on shelving banks. The thickness of the stage is probably not less than 1,000 feet, but the irregularity of dip renders it impossible to form a trustworthy estimate.

The Utatur beds form the western portion of the Cretaceous area throughout being in general from three to five miles broad, except to the northward where the breadth of the outcrop diminishes to about half-a-mile at Olappadi in consequence of overlap by the strata of the next higher stage. At the extreme northern point of the area, both the Utatur and Trichinopoly stages are completely overlapped by the uppermost subdivision. The Utatur beds are not represented in either the Vriddhachalam or Pondicherry areas.

Coral-reef Limestone.—At or near the base of the Utatur stage, as already mentioned, there are in several places large masses of limestone; these, where no lower beds of the stage are present, rest either upon the Gondwana plant beds or, more frequently, upon the gneiss. The rock is a pale-coloured, nearly pure limestone, compact and homogeneous except where it has a flaggy structure, and is irregularly banded with white streaks which on weathered surfaces exhibit the corals of which they are composed. Sometimes the mass of the rock also abounds in corals, though more frequently no organic structure can be detected.

The usual position of this limestone, which resembles precisely a present-day coral limestone, is at the base of the Utatur stage, resting upon older rocks. The coral reefs present the appearance of having been frequently exposed to denudation during the deposition of the later Utatur beds, and the calcareous bands found in places amongst these younger sediments were no doubt derived from the waste of the reefs. The coral limestone has survived in the form of small isolated patches scattered along the western and southern margins of the Cretaceous outcrop. By far the largest outcrop of the limestone, extending with one or two breaks for about six miles with a considerable breadth, is situated close to the village of Kallakkudi (Kallakhudi; Caligudi; Kalligadi; Cullygoody), on the southern boundary of the Cretaceous area twenty miles northeast of Trichinopoly town, and is unconformably overlain by beds of the Trichinopoly stage.

Boulder beds.—In places there is at the base of the Utatur stage a boulder bed which would appear to belong to the Utatur group rather than to the Upper Gondwanas. Boulder beds do occur within the local Gondwana deposits, but that at Kallakkudi, for instance, underlying the coral-reef limestone, contains a *Belemnite* and other marine fossils; the *Belemnite* is said to bear some resemblance to an Utatur species but, according to Mr. H. F. Blanford, the rest of the fossils have not been met with in either the Utatur or Trichinopoly stage. Whether the Kallakkudi boulder bed, therefore, belongs to the Cretaceous Utatur stage or is nearer in age to the Utatur Plant Beds with their Jurassic plant impressions is a matter for further investigation.[1]

Some of the boulder beds in the vicinity of Utatur have been found by H. C. Das Gupta to be phosphatic and to contain minute foraminifera such as *Globigerina, Cristellaria, Nodosaria* (?), and *Textularia*.[2] Mr. L. R. Rao describes the phosphatic nodules as abundant in the neighbourhood of Utatur, occurring often in bunches, varying in size from that of an egg to that of an orange, and in shape from spherical balls to fantastic masses.[3] They contain numerous foraminiferal remains and frequently enclose larger fossils such as ammonites. Some of them show distinct septarian structure with radiating rays composed mostly of gypsum, partly of calcite. About 50 per cent. of the rock consists of calcium phosphate, the rest being clay, calcium carbonate, silica, some ferruginous material, and a little glauconite.

Coastal character.—The coral reefs appear to have been scattered over the sea bottom in shallow water off the coast, at the commencement of the period during which the Cretaceous deposits of southern India were formed. The remaining beds of the Utatur stage were probably deposited in water of moderate depth, and some of them appear to have accumulated on submarine banks formed in tidal channels; hence current-bedding is so prevalent in the rocks. The coarser constituents of the rocks northward seem to indicate that the current which carried the sediment flowed from that direction, and the occurrence of littoral forms of mollusca in greater abundance throughout the northern parts of the area may be accounted for on the same supposition. The beds in the southern portion of the Utatur area appear to have been formed of fine silt deposited in a bay where the force of the current was less than it was to the north, the fossils which occur being mostly the remains of pelagic animals such as belemnites, a few ammonites—chiefly of the *cristati* group—or else peculiar forms of Vermetidæ (*Tubulostium discoideum* and *T. callosum*) of muddy proclivities. The ammonites and nautili, which are numerous in the north, are scarce in the southern portion of the area. Cycadaceous fossil wood, sometimes bored by *Teredo* and members of the closely related Pholadidæ abounds in certain parts of the group; its abundance affords further confirmation of the belief that the Utatur beds were laid down in the neighbourhood of a coast.

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[1] H. F. Blanford, *Mem.* IV, 47 (1862).

[2] *Rec.* LIV, 338 (1922).

[3] *Quart. Journ. Geol. Min. & Met. Soc. Ind.*, Vol. III, 49-50 (1931).

Fauna.—From the Utatur beds have been obtained the following fossils, determined by Dr. F. Stoliczka, the corals in 1873, the Echinodermata in 1873, the Bryozoa in 1872, the Brachiopoda in 1872-3[1], the Lamellibranchiata in 1871[2], and the Gastropoda[3] in 1868[4]; the belemnites and nautiloids have been revised and the lists of mollusca reinforced from Dr. Spengler's lists[5] and the ammonites from those of Dr. Kossmat[6]; the fishes were determined by Sir Philip Egerton.[7]

Spongiæ—
  Siphonia piriformis Goldf. (found in the Cenomanian of Europe),

Vermes—
  Serpula ootatoorensis Stol.

Anthozoa—
  Caryophyllia cupuliformis Stol.,
    ,, *granulifera* Stol.,
    ,, *gracilis* Stol.,
  Platycyathus indicus Stol.,
  Trochosmilia brevicula Stol.,
    ,, *camura* Stol.,
    ,, *tuba* From. (found in the Turonian of France),
  Lophosmilia similaris Stol.,
  Epismilia crassisepta Stol.,
  Psammosmilia orientalis Stol.,
  Stylina multistella Stol.,
    ,, *grandis* Stol.,
  Thecosmilia geminata Stol. (showing affinities with the genus *Euphyllia*),
  Holocoenia ramosa Stol.,
  Astrocoenia retifera Stol.,
    ,, *reussiana* Stol.,
  Mycetophyllia (?) *stellata* Stol.,
  Stelloria arcotica Stol.,
  Heliastræa ortiva Stol.,
    ,, *rotunda* Stol. (closely allied to *H. simonyi* Reuss, from the Turonian-Senonian beds of the European Gosau),
  Placastræa elegans Stol.,
  Isastraea expansa Stol.,
    ,, *siva* Stol. (closely allied to *I. profunda* Reuss, from the Gosau),
    ,, *cyathina* Stol.,
    ,, cf. *hörnesi* Reuss (Species found in the Gosau),
  Latimœandra obconica Stol.,
    ,, *gyrina* Stol.,
    ,, *crassa* Stol.,
    ,, *interrupta* Stol.,

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[1] *Pal. Ind.*, Ser. VIII, Vol. IV.

[2] *Ibid.*, Ser. VI, Vol. III.

[3] *Ibid.*, Ser. V, Vol. II.

[4] Stoliczka's lists include many previous determinations by Professor Edward Forbes.

[5] *Beitr. z. Paloeont. Österreichungarns*, Vol. XXIII, 151-152 (1910).

[6] *Ibid.*, Vol. XI. 142-148 (1898).

[7] *Q. J. G. S.*, Vol. I., 164-171 (1845).

Anthozoa—*contd.*

Latimæandra (? *Mæandrastræa*) *concentrica* Reuss (a form from the Gosau),
Thamnastræa hieroglyphica Stol. (closely allied to the European *Th. decipiens* Mich.),
,, *crassa* Stol.,
,, *pullata* Stol. (closely resembling the European *Th. tenuissima* M.-E.),
,, *induta* Stol.,
Dimorphastræa patellaris Stol.,
Comoseris oldhamiana Stol. (said to resemble closely the Jurassic *C. irradians* M.-E.),
Thecoseris agaricina Stol.,
Eupsammia varians Stol. (a variable species),
,, *denotata* Stol.,
Coscinaræa cf. *mammillata* Reuss (species found in the Gosau),
Heliopora edwardsiana Stol. (shows close resemblances to the Recent *H. coerulea* Grimm).

Echinoidea—

Hemiaster similaris Stol. (closely resembling *H. perroni* Etall. from the Cenomanian of France),
,, *frontacutus* Stol.,
,, *vicinus* Stol.,
,, *inaequalis* (Forb.) (a European form; Forbes' "*Brissus inæqualis*"),
Cassidulus (*Pygorhynchus*) *emys* Stol. (closely allied to the European *C. aequoreus* Mort. apud d'Orb.),
,, ,, *planatus* (Forb.)
Cidaris hirudo Sorig (found in the Cenomanian and Upper Greensand of Europe).
,, cf. *vesiculosa* Goldf. (species commen in the Cenomanian and Upper Greensand of Europe),
,, cf. *subvesiculosa* d' Orb. (species common in the Turonian and Senonian of Europe),
,, cf. *faringdonensis* Wright (species fourd in the Aptian or Albian of Europe).

Vermes—

Serpula aff. *collaria* Wann.

Brachiopoda—

Rhynchonella mutua Stol. (said to resemble the Jurassic *R.* (*Rhactorhynchia*) *pinguis* (Roem.),

Terebratula capillata d'Arch. (found in the Cenomanian of Europe),
,, *utaturensis* ("*ootatoorensis*") Stol.,
,, *diphimorpha* Stol.,
,, (*Rectithyris*) *depressa* Lam. (found in the Cenomanian of Europe),
,, (*Concinnithyris*) *obesa* Sow. (found in the Albian, Cenomanian and Turonian of Europe),
Terebratulina relicta Stol.,
Kingena lima Defr. (found in the Cenomanian, Turonian and Senonian of Europe).

Lamellibranchiata—

Teredo partita Stol. (found boring in fossil wood),
,, *crassula* Stol. (found in fossil wood),
,, *torulosa* Stol. (found in fossil wood),
Turnus lapidarius Stol. (found boring in sandstone),
Martesia tundens Stol. (found boring in fossil wood),
Parapholas mersa Stol. (found in fossil wood),
Rocellaria guttula Stol. (generally found boring in oyster shells),
Corbula minima d'Orb.,
Cuspidaria [*Neaera*] *detecta* (Stol.),
Saxicava tenella Stol.,
Tellina (*Arcopagia*) *mendosa* Stol.,
,, ,, *discites* Stol.,
,, (*Tellinides*) *depressa* Stol.,
Tapes (*Icanotia*) *pondicherriensis* (Forb.) (Zittel calls it "*Iscanotia*"),
Meretrix (*Callista*) *fabulina* (Stol.) (found also in the Trichinopoly stage),
,, (*Caryatis*) *turgidula* (Stol.),
Cardium (*Trachycardium*) *productum* Sow. (a cosmopolitan species occurring throughout Europe in the Cenomanian, Turonian and Senonian).

Lamellibranchiata—*contd.*

Cardium (*Protocardia*) *altum* Sow.,
,, ,, *bisectum* Forb.,
,, (*Fragum*) *praecurrens* Stol.,
Sphærulites indica Stol. (according to Douvillé this rudistid is too badly preserved to be determinable.)[1],
Lucina fallax Forb. (found also in the Ariyalur stage),
,, (*Myrtea*) *arcotina* Stol. (found also in the Trichinopoly and Ariyalur stages),
Opis repleto Stol.,
Opisoma geinitziana Stol. (closely allied to *P. bicornis* Gein. from the Cenomanian-Turonian (Plæner) beds of Saxony),
Astarte (*Grotriania*) *jugosa* (Forb.),
Circe (*Gouldia*) *planissima* (Forb.),
Leda [*Nuculana*] *socialis* (Stol.),
Nucula bidorsata Stol.,
Nuculina [*Nucinella*] *glabrata* (Stol.),
Glycimeris [*Axinaea*] *cardioides* (d'Orb.) (found also in the Trichinopoly stage).
Isoarca gibba Stol.,
Trigonoarca gumana (Forb.) (allied to *T. crassitesta* Zitt. from the Gosau),
,, cf. *abrupta* (Forb.) (found by Dr. Matley).[2]
Arca filistriata Stol.,
Lithodomus [*Lithophagus*] *curta* Stol.,
,, ,, *subcylindrica* Stol. (cf. *L.* [*L.*] *manuanensis* Bull.-Newt. from the Lower Senonian of Zululand),
Pinna laticostata Stol.,
,, *intumescens* Stol.,
Aucella parva Stol.,
Inoceramus geinitzianus Stol. (? found in the Plæner of Saxony; also in the Trichinopoly stage),
,, *labiatus* (Schloth.) (found in the Turonian of Europe and the United States; the equivalent of *I. mytiloides* Mant.),
,, aff. *concentricus* Park,
,, *bohemicus* Leonh. (European form),
Lima (*Plagiostoma*) *utaturensis* (Stol.) (Stoliczka's "*Radula* (*Plagiostoma*) *ootatoorensis*")
,, ,, *interpunctuata* (Stol.) (Stoliczka's "*Radula* (?*Plagiostoma*) *interpunctuata*"),
,, (*Limatula*) *persimilis* (Stol.) (Stoliczka's "*Radula* (*Limatula*) *persimilis*"; closely allied to the European *L. semisulcata* (Nilss.)
,, *insignis* (Stol.) (Stoliczka's "*Radula insignis*"),
Ctenostreon complanatum Stol.,
Pecten verdachellensis Forb.,
,, [*Vola*; *Janira*] *quinquecostatus* Sow. (a well known species ranging from the Albian to the Senonian in Europe, Syria, Natal, Portuguese E. Africa, Borneo, Zululand, Pondoland, etc. and elsewhere; found also in the Trichinopoly and Ariyalur stages).
,, ,, ,, *lævis* (Drouet) (found in the Cenomanian of Europe),
,, (*Syncyclonema*) *obovatus* Stol.,
,, ,, *sivaicus* Stol.,
Hinnites andurensis Stol. ("*H. andoorensis*"),
Plicatula sessilis Stol.,
Spondylus subcostulatus Stol. (closely allied to the European *S. globulosus* d'Orb.),
Exogyra haliotoidea (Sow.) (found in the Cenomanian of Europe),
,, *costata* Say (found in the Upper Cretaceous of North America and Portuguese East Africa; closely allied to the European *E. overwegi* Buch),
,, *suborbiculata* (Lam.) (found in the Upper Greensand and Cenomanian throughout Europe and N. W. Asia),
,, *canaliculata* (Sow.) (found in the Cenomanian of Europe),
Gryphæa pudurensis Stol. ("*G. poodoorensis*"),
,, *vesiculosa* (Sow.) (found in the Albian and Cenomanian of Europe and elsewhere),
Alectryonia diluviana (Lin.) (found in the Cenomanian throughout Europe and in N. W. Asia; also in the Trichinopoly stage),
,, *carinata* (Lam.) (found in the Cenomanian of Europe, N. W. Asia and N. Africa; also in the Trichinopoly stage).

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[1] *Vide Mem. Soc. geol. France, Pal.* XVIII, Fasc. 1 (1910).

[2] *Rec.* LXI, 339 (1928).

Gastropoda—

Rostellaria turonica Spengl.,
Alaria parkinsoni (Mant.) (found in the Albian and Cenomanian of Europe; characteristic of the Gault),
Eocypræa pilulosa Stol., (Stoliczka's "*Cypræa* (*Luponia*) *pilulosa*"),
Fusus verticillatus Stol.,
Columbellina sp.,
Nerinea incavata Bronn. (found in the Turonian of Gosau),
,, *blanfordiana* Stol. (resembling the Gosau species *N. buchi* Kefst.),
Cerithium fertile Stol.,
Turritella (?) *nerinea* Röm. (found in the Senonian of Europe),
,, *acanthophora* Müll. (found in the Cenomanian of Europe and Upper Cretaceous of Madagascar),
,, (*Zaria*) *breantiana* d'Orb. (occurs in Natal; a comparable form found in Portuguese E. Africa),
Scalaria (?) *clementina* Mich. (found in the Gault of Europe),
Vermetus (*Tubulostium*) *discoideus* (Stol.),
,, ,, *callosus* (Stol.),
Straparollus indicus Stol.,
Littorina attenuata Stol.,
,, *strenua* Stol.,
Fossarus odiensis Spengl.,
Rissoa tropica Stol.,
Tylostoma utaturense (Stol.) ("*Tylostoma ootatoorense*"),
(?) ,, *terebralis* Stol.,
Ampullina bulbiformis (Sow.) (found in the Turonian and Senonian of Europe),
Sigaretus cenomanensis Spengl.,
Gyrodes pansus Stol. (closely related to some forms of *Natica canaliculata* from the Plæner of Germany, and almost indistinguishable from *Gyrodes conradi* Meek from Texas; cf. also *G. manuanensis* Bull.-Newt. from the Lower Senonian of Zululand,
Vanikoro [*Narica*; *Neritopsis*] *munita* (Forb.),
Neritopsis crassa Stol.,
Patella sp.,
Astralium carnaticum Stol.,
,, (*Calcar*) *jugosum* (Stol.),
Solarium vylapaudiense Stol.,
Solariella radiatula (Forb.) (found in the Senonian of Europe; and Upper Campanian of Pondoland),
,, *strangulata* Stol.,
Delphinula annularis Stol.,
Pleurotomaria loricatula Stol.,
,, *glabella* Stol.,
,, (*Leptomaria*) *indica* Forb. (very similar to many species in the Upper Cretaceous of Europe),
Emarginula cf. *guerangeri* d'Orb.,
Actæon junceus Stol.,
Actæonella cylindracea (Stol.),
Cinulia (*Avellana*) *elongata* Guér. (found in the Cenomanian of Europe),
Phasianella incerta Forb.[1]

Scaphopoda—

Dentalium (*Antalis*) *glabratum* Stol.

Cephalopoda[2]—

Nautilus sphaericus Forb. (this is an Ariyalur species, and only a single specimen is claimed to have been found in the Utatur, N. W. of Odiyam),
U. ,, *huxleyanus* Blanf. (found also in the Trichinopoly and Ariyalur stages; allied to the United States species, *N. dekayi*),
M. ,, *clementinus* d'Orb, var. *indicus* Spengl. (includes the "*N. splendens*" of Blanford and in part the *N. bouchardianus* of d'Orbigny (apud Blanford); *forma typica* found in the Gault of Middle Europe),
U, ,, *angustus* Blanf. (found also in the Ariyalur),

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[1] C. A. Matley. *Rec.* LXI, 339 (1928).

[2] L.=characteristic of the Lower Utatur;
M.= ,, ,, ,, Middle Utatur;
U.= ,, ,, ,, Upper Utatur.

Cephalopoda—*contd.*

M. *Nautilus fleuriausianus* d' Orb., var. *indica* Spengl. (*forma typica* found in Madagascar, and in the Cenomanian of Middle Europe and Tunis),

M. ,, cf. *applanatus* Zitt. (species found in the White Chalk of Libya; allied to *N. cantabrigiensis* Foord from the Cenomanian of England),

U. ,, [? *Cymatoceras*] *justus* Blanf.,

L. *Cymatoceras negama* (Blanf.) (? found in the Cenomanian of Madagascar),

L.M. ,, *kayeanum* (Blanf.) (equated by Stoliczka with *Nautilus neocomiensis* d'Orb., very close to *C. radiatum* Sow. from the Aptian-Cenomanian of Europe),

L. ,, *kossmati* Spengl. (the "*Nautilus pseudo-elegans*" of Blanford and Stoliczka; found in the Albian of Zululand),

L. ,, *virgatum* Spengl. (allied to *C. rugatum* Fr. & Schl. from Bohemia, and to *C. pseudo-elegans* d'Orb. from the Neocomian of Middle Europe and the Cenomanian of eastern Asia, and also to *C. charlottense* Wh. and *C. suciense* Wh. from the Pacific coast of N. America),

L. ,, *crebricostatum* (Blanf.) (A Malagassy form; allied to *C. cenomanense* Schl. from the Cenomanian of Middle Europe. Stoliczka was unable to distinguish between this species and *C. negama*),

L. ,, *pseudonegama* Spengl.,

L. ,, *semilobatum* Spengl.,

U. ,, cf. *atlas* Wh. (a variety is found in Madagascar; equivalent to *C. elegans* d'Orb. from the Cenomanian of Middle Europe),

L. *Hercoglossa utaturensis* (Stol.) (Stoliczka's "*Nautilus ootatoorensis*").

L. *Belemnites seclusus* Blanf.,

L. ,, (*Hibolites*) *ultimus* d'Orb. (found in Europe and the Cenomanian of Madagascar; the equivalent of *B. semicanaliculatus* of Stoliczka and *B. stilus* of Blanford),

L. ,, (*Pseudobelus*) *stoliczkai* Spengl. (equivalent in part to *B. fibula* of Blanford and Stoliczka),

L. ,, ,, *blanfordi* Spengl. (equivalent in part to *B. fibula* of Blanford and Stoliczka),

L. *Phylloceras ellipticum* Kossm. ("*Ammonites subalpinus*" of Stoliczka; found in the Cenomanian of Zululand),

,, *velledæ* Mich. (found in N. Africa, Madagascar, Vancouver, Saghalin and Manchuria, in the Gault and Lower Cenomanian of Europe and the Albian and Cenomanian of Zululand),

,, *improvisum* (Stol.),

,, *whiteavesi* Kossm. (a Vancouver form; cf. *P. ezoense* Jok. from the Cretaceous of Japan),

L. *Lytoceras mahadeva* (Stol.) (cf. *L. batesi* Meek from the Middle Cretaceous of California and Queen Charlotte Island),

L. *Gaudryceras sacya* (Forb.) (found in the middle Cretaceous of E. Africa, Zululand, Japan, Saghalin, California, Vancouver and Queen Charlotte Island),

,, *multiplexum* Kossm. (found in Madagascar and ? Antarctica, and in the Middle Cretaceous of Saghalin),

L. ,, *vertebratum* Kossm. ("*Ammonites kayei* Stol. non Forb."),

,, *madraspatanum* (Stol.),

,, *involvulum* (Stol.),

,, *revelatum* (Stol.),

,, *odiense* Kossm. (found in the Cenomanian of Zululand),

,, *marut* (Stol.) (cf. *G. agassizianum* Pict. from the Gault of Switzerland),

L. *Tetragonites timotheanus* Mayor (found in Saghalin, Queen Charlotte Island, Califorina, the Cenomanian of Zululand and Madagascar, and in the Upper Gault and Lower Cenomanian of Europe),

,, *kingianus* Kossm.

L. *Desmoceras latidorsatum* (Mich.) (found in the Middle Cretaceous groups of Europe),

,, *inane* (Stol.) (found in the Cenomanian of Zululand),

Puzosia planulata (Sow.), var. (*forma typica* widely distributed in the Cenomanian of Europe and Brazil, and identified in the Cenomanian of Zululand),

,, *crebrisulcata* Kossm. (related to *P. gaudama* (*non* Forb.) from Japan),

L. ,, *compressa* Kossm. (found in the Cenomanian of Madagascar; Stoliczka's "*Ammonites durga*").

Cephalopoda—*contd.*

Puzosia stoliczkai Kossm. (Stoliczka's "*Ammonites beudanti*"—perhaps a *Uhligella*; found in the Cenomanian of Zululand),
,, *insculpta* Kossm.,
L. ,, *bhima* (Stol.) (found in Natal and in the Albian of Zululand, and related to *P. octosulcata* Sharpe from the Cenomanian of England),
,, *aliena* (Stol.),
,, *denisoniana* (Stol.),
L. *Holcodiscus cliveanus* (Stol.)
L. ,, *moraviaturensis* (Stol.),
L. ,, *papillatus* (Stol.),
Pachydiscus rotalinus (Stol.),
Scaphites similaris Stol. (related to *S. æqualis* Sow. from the Cenomanian of Europe),
,, *obliquus* Sow.,
,, *kingianus* Stol.,
L. *Placenticeras warthi* Kossm.,
Forbesiceras largilliertianum d' Orb.(found in the Cenomanian of Zululand and the Upper Cenomanian of Europe),
,, *subobtectum* (Stol.) (cf. *F. obtectum* Sharpe from the Upper Cenomanian of England),
Acanthoceras turneri White (found in the Chico beds of California),
,, *newboldi* Kossm. (found in Madagascar and in the Cenomanian of Zululand, and in the Upper Cenomanian of England),
,, ,, var. *spinosa* (found in Madagascar and the Cenomanian of Zululand, and in the Upper Cenomanian of England),
,, ,, var. *planecostata* (found in Madagascar and in the Upper Cenomanian of England),
,, *hunteri* Kossm. (allied to *A. cenomanense* d'Arch. from the Upper Cenomanian of Europe),
,, *cenomanense* d'Arch. (found in the Upper Cenomanian of Europe),
,, *naviculare* Mant. (found in the Upper Cenomanian of Europe),
,, *choffati* Kossm. (found in the Cenomanian of Zululand),
,, *gothicum* Kossm.,
,, *harpax* (Stol.) (a closely allied form found in the Upper Cenomanian of Syria),
,, *centagonum* J. Browne & Hill (found in the Upper Cenomanian of Europe),
,, *tropicum* (Stol.),
,, *medlicottianum* (Stol.),
,, *ornatissimum* (Stol.) (probably identical with *A. deverioides* Gross., from the Lower Turonian of France),
,, *cunningtoni* Sharpe, var. *cornuta* Kossm. (*forma typica* found in the English Chalk),
,, *meridionale* (Stol.)
,, *aberrans* Kossm.,
,, *colerunense* (Stol.),
,, *footeanum* (Stol.) (related to *A. pedroanum* White from the Cenomanian of Brazil),
,, *conciliatum* (Stol.) (related to *A. nodosoides* Schloth. from the Lower Turonian of Europe and Syria),
,, *crassitesta* (Stol.),
L. *Acanthoceras mantelli* (Sow.) ("*mantelliceras*"; found in the Upper Cenomanian of Europe),
,, *laticlavium* Sharpe, var. *indica* Kossm. ("*mantelliceras*"; *forma typica* found in the Upper Cenomanian of Europe),
,, *ushas* (Stol.),
,, *morpheus* (Stol.),
,, *vicinale* (Stol.) (found in the Cenomanian of Madagascar; related to *A. swallowi* Shum. from the Lower Turonian, U. S. A.),
,, *discoidale* Kossm. ("*Mantelliceras*"),
Baculites gaudini Pict. (found in the Lower Cenomanian of Switzerland),
,, cf. *baculoides* Lam. (species found in the Cenomanian of Europe),
Neoptychites telinga (Stol.) (found in the Turonian of Algiers),
,, *xetra* (Stol.),
L. *Stoliczkaia dispar* (d'Orb.) (found in the Lower Cenomanian of Europe and West Africa, and perhaps in the Albian of Zululand),
,, *tetragona* Neum.
L. ,, *crotaloides* (Stol.),
L. ,, *argonautiformis* (Stol.),

Cephalopoda—*contd.*

L. *Hamites armatus* Sow. (found in the Lower Cenomanian of Europe),
,, *angulatus* Stol.,
,, *problematicus* Stol.,
,, aff. *meyrati* Ooster (species found in the Lower Cenomanian of Switzerland)
Hamites glaber Whit. (found in the middle Cretaceous of Queen Charlotte Island),
L. *Anisoceras oldhamianum* Stol.
Hamulina sublævis Stol.,
L. *Diptychoceras forbesianum* (Stol.) (found in New Zealand, and in the Cenomanian of Madagascar),
Ptychoceras tropicum Kossm. (cf. *P. gaultinum* Pict. from the Greensand of Switzerland),
L. *Turrilites bergeri* Brongn. (found in the Upper Gault and Lower Cenomanian of Europe and N. Africa),
,, *tuberculatus* Bosc. (found in the Lower Cenomanian of Europe and Madagascar),
,, *circumtaeniatus* Kossm. (found in New Zealand; related to *T. gresslyi* Pict. from the Gault of Switzerland),
,, *costatus* Lam. (found in the Middle and Upper Cenomanian of Europe, and in the Cenomanian of Zululand, N. Africa and Tibet),
,, *cunliffeanus* Stol.,
L. ,, *spinosus* Kossm. ("*T. brazo-ensis* Stol.," "non Romer"),
Holcostephanus superstes Kossm. (found in the Turonian of Algiers and possibly in the Upper Cenomanian of Brazil),
,, *rudra* (Stol.),
Schlœnbachia obesa (Stol.) (cf. "*Ammonites goupilianus* d'Orb. from the Cenomanian of Europe),
Schlœnbachia propinqua (Stol.),
,, *utaturensis* (Stol.) (Stoliczka's "*Ammonites ootatoorensis*"),
L. ,, *corrupta* (Stol.),
L. *Pervinquieria inflata* (Sow.) (found in the uppermost Albian of Europe, and elsewhere),
,, *inflata* var. *orientalis* Kossm.,
,, ,, var. *æquatorealis* Kossm. (a cosmopolitan type; found among other places in Angola and Madagascar),
Neokentroceras gracillimum Kossm. (cf. *Schlœnbachia tectoria* White from the Cenomanian of Brazil),

Crustacea—
?*Haploparia* sp.

Pisces—
Pycnodus ? sp.,
Otodus basalis Eg.,
,, *nanus* Eg.,
,, *minutus* Eg.,
Odontaspis constrictus Eg.

From the Utatur beds probably came the fruit-like body, apparently part of an Angiosperm, mentioned by Foote.[1] A specimen of cycad wood found near Trichinopoly belongs to the recent family of Cyatheaceæ and has been described by Feistmantel as *Protocyathea trichinopoliensis*; whether it came from the Utatur or the Trichinopoly stage is uncertain.[2]

The rich fauna, comprising some 280 species, has yielded an especially large number of cephalopods, the great majority of which are not found in either the Trichinopoly or the Ariyalur stages. Although some of the early identification with European forms have been found to be erroneous, there is undoubtedly some relationship with the cephalopod fauna of the Cenomanian of Europe. The majority of the Utatur fossils, however, show closer affinities with those of the Pacific provinces. A very large proportion of the cephalopods come from the neighbourhood of two villages, Odiyam (Odium) and Maruvattur (Maravatur), some twelve miles northeast of Ariyalur. The species of Gastropoda are far less than they are in either of the other two groups, and the majority are littoral forms. The only fossils of much importance beside the Cephalopoda and Mollusca are the corals which, from the prevalence of reefs at the base of the stage, are superbly represented by no less than 23 genera and 41 species. Those species of lamellibranchs, gastropods, brachiopods, echinoderms and corals, which are common to other parts of the world, belong for the most part to the Cenomanian or higher groups, thus supporting the evidence of the cephalopods.[1]

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[1] *Rec.* XII, 162 (1879).

[2] *Rec.* X, 136-137 (1877).

At the base of the Utatur stage occur *Pervinquieria inflata*[2]—an ammonite especially characteristic of the Atlantic province—and several allied species *Hamites armatus*, *Turrilites bergeri*, *Tetragonites timotheanum*, *Stoliczkaia dispar* and other forms, all of which characterise the topmost Albian or the base of the Cenomanian in Europe. This basal sub-stage, the characteristic cephalopods of which have been labelled "L" in the above list, is seen between Kuluppatti (Kulappadi; Kalpadi; Cullpady; Culputty) and Maruvattur in the form of soft marls and clays, with intercalated bands of fossiliferous yellow limestone in which are included rolled blocks of gneiss and coral limestone occasionally of some size.[3] In higher beds the extraordinarily rich *Acanthoceras* fauna, of the type of the world-wide *A. rhotomagense* Brongn. (*A. mantelli*, etc.), coupled with a large number of other well marked forms such as *Turrilites costatus*, *Desmoceras latidorsatum* and *Alectryonia carinata*, identify a middle sub-stage, which forms part of a thick and more sandy succession, as the equivalent of the Middle and Upper Cenomanian. In the uppermost beds of the Utatur stage, the typical *Acanthoceras rhotomagense* element has disappeared and given place to ammonites related to the European Turonian *Acanthoceras* [*Mammites*] *nodosoides* (*A. conciliatum*, *A. ornatissimum*, *A. discoidale*, *A. vicinale*, etc.) and to the readily identified *Inoceramus labiatus*, a lamellibranch typical of the Lower Turonian of Europe. In this Upper Utatur sub-stage, exposed around Cunum (Kannam) and Monglepady and made up of lustrous shales with subordinate thickness of moderately hard sandstone or brownish argillaceous limestone, occurs the beautiful *Nautilus huxleyanus* which ranges up into the Trichinopoly and Ariyalur; most of the specimens of the variety of *Puzosia planulata* also belong to this horizon.

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[1] Vredenburg divides and correlates the Utatur stage as follows ("A Summary of the Geology of India", 2nd Edt., 95 (1910):

Upper. Beds with *Acanthoceras conciliatum* and *Nautilus huxleyanus* (Turonian).

Middle. Acanthoceras beds with numerous species of *Acanthoceras* and with *Turrilites costatus*. (Cenomanian).

Lower. Schlœnbachia beds, with *Schlœnbachia inflata*, *Turrilites bergeri* and *Hamites armatus*. (Gault).

The Trichinopoly stage is regarded by this author as the equivalent of the Lower Senonian; the Ariyalur he assigns to the Campanian, and the Niniyur to what he calls the Mæstrichtian and Danian.

Kossmat considered the uppermost beds of the Utatur stage to be of Lower Turonian age.

[2] *Pervinquieria inflata* is a common ammonite in the European Gault (Albian).

[3] F. Kossmat. *Beitr. z. Pal. Osterr-Ungarns*, XI, 128 (1898).

TRICHINOPOLY STAGE.

Lithological Composition.—The Trichinopoly stage, restricted as it is to the district of Trichinopoly, is, nonetheless, not a well chosen name since it covers a smaller area in that district than either of the other two groups and is exposed nowhere near the town of Trichinopoly.[1] To the south it consists chiefly of sands and clays, very irregularly bedded, with a few bands of limestone and some conglomerates, and differs lithologically only in one important respect, which will be described in due course, from the Utatur group. North of the parallel of Utatur, regular bands of shell limestone make their appearance in the lower horizons until the whole group is composed of regularly stratified alternations of sand, sandy clay and shale, with bands of shell limestone, calcareous grit and conglomerate.

The peculiarity by which the Trichinopoly beds—and incidentally the Ariyalur beds also—of the southern part of the outcrop are distinguished from the Utatur is the occurrence of granite pebbles in considerable numbers in the gravels and conglomerates of the two younger stages, as contrasted with their absence in the oldest of the three subdivisions. The materials of the few conglomeratic or gravelly beds which occur in the Utatur stage are derived either from the gneiss or from the coral-reef limestone, whilst in the two upper stages conglomerates are more frequently met with, and loose masses of unstratified gravel with rolled pebbles composed almost entirely of granitic materials and resembling the shingle of a sea beach, are of common occurrence. The source of the granitic pebbles is thought to have been a broad belt of granitic rock north of the Cauvery alluvium, stretching from east to west for many miles and disappearing eastwards beneath the Cretaceous deposits, the inference being that this band of granite lay in all probability beneath the sea during the deposition of the Utatur sediments but was elevated above water in the interval between the Utatur and Trichinopoly ages.[2]

The shell limestone of Garudamangalam, east of Utatur, and of other places, is a very fine, hard, bluish grey, translucent rock, usually abounding in beautifully preserved shells, chiefly gastropods and lamellibranchs, which not only retain their original polish but occasionally even the coloration of their surfaces. This rock, which is known as "Trichinopoly marble" and is largely quarried for ornamental purposes, has yielded a considerable proportion of the stage fauna; occasionally it contains pebbles of granite or fragments of fossil wood, any of which are sufficient to distinguish it, even when otherwise unfossiliferous, from the Utatur limestones.

Coastal character.—Even more characteristically than the Utaturs, the Trichinopoly beds are littoral deposits of a shallow sea. This is proved, not only by the frequent occurrence of coarse sediment and the great irregularity of the deposits in part of the area, but by the abundance of fossil wood which is almost exclusively gymnospermous and apparently cycadaceous; tree-trunks of great size, some of them as much as three feet in diameter and sixty feet long, are met with, much of the wood being perforated by boring mollusca.

Relationships to older rocks.—The beds of the Trichinopoly stage are unconformable to the Utaturs, upon which they rest throughout the greater part of the area. The evidence of this unconformity is not confined to overlap, for in places the Trichinopoly sediments lie upon a denuded surface of the Utaturs and, along the southern edge of the area, the latter show signs of having been disturbed and faulted, probably during the period of upheaval of the granite band already mentioned, before the deposition of the Trichinopoly formation. In the southern portion of their range the Trichinopoly beds rest partly upon the coral reefs, *i.e.*, upon some of the lowest horizons of the Utatur stage, partly on the metamorphic rocks of the neighbourhood, and along a considerable portion of the boundary upon the granitic band. The unconformity is accompanied by a considerable change in the fauna from one stage to the other.

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[1] C. A. Matley. *Rec.* LXI, 338 (1928).

[2] H. F. Blanford. *Mem.* IV, 31, 108-109 (1862).

Thickness and extent.—Like the Utatur, the Trichinopoly group is so irregularly bedded, and the visible dips of its rocks are so frequently those of original deposition, that no trustworthy estimate of the total thickness can be formed. The general inclination is to the eastward, the average breadth of the outcrop is nearly the same as that of the Utatur beds, and the same minimum thickness of 1,000 feet may be assumed. The general dip of the bedding in the more regularly stratified portion of the stage to the northward averages about 6° and is lower than the dip in the underlying stage. The Trichinopoly beds thin out greatly in a northerly direction and are at length completely overlapped in turn by the Ariyalurs. Extending from S. S. W. to N. N. E., the Trichinopoly outcrop is broader in the southern half of the area, where it is about four miles across, than it is in the northern half where it never exceeds two miles in width. In thinning out northward, it disappears completely at a point some two miles south of the place where the Utaturs are similarly overlapped by the Ariyalur beds.

Along the southern boundary of the Utatur outcrop several outliers of Trichinopoly beds are found, resting partly on the Utaturs, partly on the gneiss, and occasionally overlapping the faulted boundary between the two. These small outliers, one of which, south of Tirupatur, forms the southwest corner of the whole area, are composed of coarse sands and conglomerates, usually unfossiliferous but occasionally containing *Chemnitzia undosa* and other characteristic Trichinopoly fossils; the materials of which they are formed were derived partly from the denudation of the Utatur beds but chiefly from the metamorphic rocks.

Fauna.—Of the fauna of the Trichinopoly stage, which is not quite so rich as that of the Utatur, over 185 species have been described by Stoliczka, Kossmat and Spengler; with some minor revision they are as follows (*vide* footnotes 1-4, page 1226):

Anthozoa—
  Trochocyathus affinis Stol.,
  Trochosmilia inflexa Reuss (found in the Turonian of the Gosau and France).
  Phyllocoenia multisepta Stol.,
  Astrocoenia decaphylla Mich. (found in the Turonian of Europe).
Ni. *Mycetophyllia nobilis* Stol.,
  Isastræa morchella Reuss (found in the Turonian of Europe).

Echinoidea—
  Hemiaster tuberous Stol. (provenance uncertain).

Brachiopoda—
  Rhynchonella compressa (Lam.) (found in the Upper Cenomanian and the Turonian of Europe).
  ,, *plicatiloides* Stol.,

Brachiopoda—*contd.*

Terebratula biplicata Sow., var. *dutempleana* Stol.,
Ar. ,, (*Gibbithyris*) *subrotundata* (Sow.), var. *subundata* Stol. (specific determination doubtful),
,, ,, *grandis* Sahni,
Kingena shalanurensis Stol. (allied to "*Terebratula robertoni* d'Arch."),

Lamellibranchiata—

Corbula striatuloides Forb. (perhaps equivalent to *C. cochlearia* d'Orb.),
Ar. ,, *parsura* Stol.,
,, *cancellaria* Stol.,
Ar. *Cuspidaria* [*Neaera*] *mutua* (Stol.),
Ar. *Poromya lata* Forb., (perhaps a variety of *P. globulosa* Forb.),
,, *superba* Stol.,
Spisula (*Schizodesma*) *tripartita* (Sow.) (Sowerby's "*Mactra tripartita*" *apud* Forbes),
Thracia [*Corimya*] *oldhamiana* (Stol.),
Pholadomya lucerna Roem. (found in the Upper Cretaceous of Portuguese E. Africa ; cf. *P. caudata* Roem. from the European Senonian, with which Stoliczka identified it),
,, *radiatula* Stol.,
,, *pedisulcata* Stol.,
Ar. *Panope* ["*Panopea*"] *orientalis* Forb.,
Ar. *Solen* (*Siliqua*) *limatus* Stol.,
Ar. ,, (*Pharella*) *delicatulus* Stol.,
Tellina (*Tellinella*) *petrosa* Stol.,
,, (*Palæomæra*) *inconspicua* (Sow.),
,, (*Linearia* ?) *semisculpta* Stol.,
Donax sp.,
Meretrix (*Dosiniopsis* ?) *plana* (Sow.) (found in the Upper Greensand of Europe; Stoliczka's "*Cytherea plana*"),
,, (*Callista*) *fabulina* (Stol.) ("*Cytherea*"),
Ar. ,, (,,) *vagrans* (Stol.) (,,)
,, (,, ?) *solitaria* (Stol.) (,,)
Ar. ,, (*Caryatis*) *telugensis* (Stol.) (,,)
,, (,,) *intercisa* (Stol.) (,,)
Eocypræa newboldi (Forb.) ("*Cypræa newboldi* Forb.)
Ar. *Cyprimeria analoga* (Forb.)
,, *oldhamiana* Stol.,
Astarte (*Eriphyla*) *lenticularis* (Goldf.) (the equivalent of "*Lucina lenticularis* Goldfuss" from the Upper Cretaceous of Germany ; found in the Senonian of Natal, Zululand and Pondoland),
?*Trapezium* sp.,
Ar. *Venericardia obtruncata* Stol.,
[*Cyprina*] *Arctica forbesiana* Stol., —Cox retains *Cyprinia*, Bullen Newton's *Veniella forbesiana*, Choffat's "*Roudaireia*" *forbesiana* (found in the lower Senonian of Zululand and Upper Campanian of Pondoland) ; also in Angola and Tunis.
Cicatrea cordialis Stol.,
Cardium (*Trachycardium*) *incomptum* Sow.,
,, (*Acanthocardium*) *pullatum* Stol.,
,, (?*Lævicardium*) *scrobiculatum* Stol.,
,, (*Protocardia*) *hillanum* Sow. (a widespread form ; found in the Cenomanian, Turonian and Senonian of Europe, Africa, N. America and other places, especially characteristic of the Turonian),
,, (,,) *pondicherriense* d'Orb.,
Ut. *Cardium* (*Fragum*) *praecunens* Stol.,
Chama deplanata Stol.,
Ut. Ar. *Lucina* (*Myrtea*) *arcotina* Stol.,
Circe (*Gouldia*) *trigonioides* Stol.,

Ar. *Trigonia scabra* Lam. (common in the Upper Cretaceous of Europe),
,, *tuberculifera* Stol. (closely resembling *T. ventricosa* Krauss, a very characteristic lamellibranch in the Uitenhage series of South Africa),
,, *semiculta* Forb.,
Glycimeris [*Axinea*] *cardioides* (d'Orb.),
Parallelodon [*Macrodon*] *disparile* (d'Orb.) (Walcken's genus *Nordens kjöldia*"),

Lamellibranchiata—*contd.*

Trigonoarca telugensis Stol.,
,, *abrupta* (Forb.),
,, *trichinopolitensis* (Forb.),
Arca (*Barbatia*) *diatreta* Stol.,
Myoconcha subovata Stol.,
Modiola typica Forb. (found in the Turonian of the Gosau, and the Upper Campanian of Pondoland),
Pinna complanata Stol.,
,, *arata* Forb. (closely allied to the European *P. decussata* Goldf.),
Inoceramus multiplicatus Stol.,
,, *diversus* Stol.,
,, *geinitzianus* Stol. (perhaps identical with *I. concentricus* Gein. from the Plaener of Saxony),
Pecten anapaudiensis Stol. (*P. obliquus* Sow. *apud* Forbes),
Ut. Ar. ,, [*Vola*; *Janina*] *quinquecostatus* Sow.
Ar. ,, (*Camptonectes*) *curvatus* Gein. (usually quoted as *P. virgatus* Nilss.; ranging from the Cenomanian to the Senonian in Europe),
,, (*Pseudamusium*) *garudanus* Stol.,
Plicatula multicostata Forb. (closely allied to the Gosau species *P. aspera* Sow.),
Spondylus calcaratus Forb. (allied to the European *S. truncatus* Goldf.),
Exogyra fausta Stol.,
Exogyra cf. *suborbiculata* Lam.
Alectryonia diluviana (Linné) (common in the Cenomanian of Europe, and found also N. W. Asia),
,, *amorpha* (Sow.),
,, *carinata* (Lam.) (found in the uppermost Cenomanian throughout Europe and in N. W. Asia and N. Africa),

Scaphopoda—

Dentalium (*Antalis*) *crassulum* Stol.,
,, (,,) *arcotinum* Forb.,

Gastropoda—

Angystoma arcotense Stol.,
Pugnellus contortus (Sow.) (found in the Upper Campanian of Pondoland),
Ar. ,, *granuliferus* (Stol.) (found also in the Ariyalur stage),
?Ar. ,, *uncatus* (Forb.) (a widespread form, found in Natal, Portuguese E. Africa, Chile, etc.),
Ar. *Aporrhais securifera* (Forb.),
Ar. *Aporrhais tegulata* Stol.,
Aporrhais cf. *bailyi* Eth.,
,, *trichinopolitensis* Spengl.,
,, (*Arrhoges*) *indica* (Spengl.),
Ut. *Alaria parkinsoni* (Mant.) (found in the Albian and Cenomanian of Europe),
,, *glandina* Stol.,
Ar. *Calyptraphorus palliatus* Forb.,
Pleurotoma subfusiformis d'Orb. (found near the top of the Trichinopoly stage; also in the Turonian of Gosau),
Gosavia indica Stol. (found near the top of the Trichinopoly stage; probably belong to Douville's genus *Diploconus*.
Pleurotomaria trichinopolitensis Spengl.,
Ar. *Trochus arcotensis* Forb.
Eocypræa newboldi (Forb.) ("*Cypræa newboldi* Forb".)
Protocypræa ficulina (Stol.) ("*Cypræa* (*Aricia*) *ficulina* Stol."),
,, *orbignyana* (Vred.) ("*Cypræa newboldi* Stol., non Forb."),
,, *coromandelica* (Vred.) ("*Cypræa kayei* Stol. in part"),
?Ar. ,, *kayei* (Forb.) (*Cypræa kayei* Forb.; found in the Senonian of France),
Scaphella (*Scapha*) *attenuata* (Stol.),
Volutoderma (*Rostellinda*) *stoliczkana* Dall,
,, ,, *media* Dall,
,, ,, *tenua* Dall,
,, ,, *multistriata* (Stol.) (found near the top of the stage),

Gastropoda—*contd.*
Ar. *Athleta purpuriformis* (Forb.),
Volutilithes accumulata Stol.,
?*Lyria granulosa* Stol. (provenance uncertain),
Volutomitra canaliculata Stol.,

Latirus reussianus Stol. (probably equivalent to the Gosau species *Fusus reussi* Zek.),
Fasciolaria rigida (Baily) (a common species ; found in the Cenomanian of S. Africa),
Hemifusus cinctus Stol.,
Ar. *Hemifusus* (*Mayeria*) *nodulosus* (Stol.)
?*Chrysodomus* [*Neptunea*] *excavata* (Blanf.) (found in the Upper Cretaceous of Madagascar.),
Chrysodomus gibbosa Stol.,
,, *requioniana* (d'Orb.) (found in the Turonian of France),
,, *granulata* Stol., (rare),
,, *trichinopolitensis* (Forb.)

Pollia pondicherriensis (Forb.) (some authorities regard *Pollia, Tritonidea* and *Cantharus* as synonymous genera),
Trophon oldhamianum Stol.,
Rapa andurensis (“*andoorensis*”) Stol.,
,, *nodifera* Stol.,
,, *cancellata* (Sow.) (high up in the group),
Rapana tuberculosa Stol.,
Trichotropis konincki (Müll.) (found in the Senonian of France),
,, *nodulosa* Stol.,
Ni. *Cancellaria* (*Narona*) *eximia* Stol.,
Odontostoma antiquum Stol.,
Ar. *Cerithium* [*Campanile*] *inauguratum* Stol. (found in the “Craie pisolitique” near Paris),
,, [?*Fibula*] *hispidulum* Stol. (resembling *C. hispidum* Zek. from the Gosau beds),
Ar. ,, ,, *detectum* Stol.,

Ar. ,, [?*Exelissa*] *scalaroideum* Forb.,
Ar. ,, *vagans* Stol.,
,, *clarandum* Stol.,
Ar. ,, *trimonile* Mich. (common in the Albian of France),
Potamides (*Sandbergia*) *postlallierianum* (Spengl.),
Ar. ,, ,, *crispicans* (Stol.),

Arcotia indica Stol.,
Turritella (“*Torcula*”) *affinis* Müll. (found in the Senonian of France),
Ar. ,, (“*Zaria*”) *multistriata* Reuss (found in the Turonian of Europe),
Ut. ,, ,, *breantiana* d'Orb. (found in the Upper Cretaceous of Madagascar),
Ut. ,, *acanthophora* Müll.,
,, *neptuni* Münst. (found in the Turonian of Europe),
Scalaria [*Scala*] *shutanurensis* Stol.,
Littorina inconstans Stol.,
,, *acicularis* Stol.,
,, *trichinopolitensis* Spengl.,
Ut. *Fossarus odiensis* Spengl.,
Rissoa oldhamiana Stol. (especially characteristic of the zone of *Pachydiscus caju, P. anapaudiensis* and *P. jimboi*),
Ut. ,, *tropica* Stol.,
Keilostoma politicum Stol.,
Pseudomelania [*Chemnitzia*] *undosa* (Sow.),
Ar. ?*Euchrysalis gigantea* Stol. (Stoliczka's illustration is unlike *Euchrysalis* which is a Triassic genus, but Spengler also records it),
Tylostomae nobil Stol.,
Rimella indica Spengl.,
,, *trichinopolitensis* Spengl.,
Ar. *Amauropsis pannucea* Stol.,
,, *subcancellata* Haml.,
Ut. *Ampullina bulbiformis* (Sow.) (found in the Turonian and Senonian of Europe),
,, *obliquestriata* (Forb.),
Lunatia metheroniana d'Orb. (a European species),
Euspira indrana Stol. (found near the top of the stage),
,, *mariæ* (d'Orb.),
Ut. *Vanikoro munita* (Forb.),
,, ,, var. *canaliculata* Spengl.,
Ut. Ar. *Gyrodes pansus* Stol.,

Gastropoda—*contd.*

Ar. *Gyrodes tenellus* Stol. (found in the Upper Campanian of Pondoland),
Ar. *Neritina compacta* (Forb.),
Ar. *Phasianella incerta* Forb.,
Ar. ,, *globoides* Stol.,
Ar. *Calliostoma* [*Ziziphinus*] *geinitzianum* (Reuss) (found in the Turonian of Europe),
Ut. Ar. *Solariella radiatula* (Forb.) (found in the Senonian of France and of Seghalin),
Ut. ,, *strangulata* Stol.,
Margarita orbiculata Stol.,
Cylichna alternata (d'Orb.),
Bullina cretacea (d'Orb.),
Ni. *Solidula semen* (Forb.),
Purpura indica Spengl.,
Actaeonina lineolata Reuss,
Actaeon sublaevigatus Spengl.,
Actæon seminatus Stol.,
,, *turriculatus* Stol.,
Ut. *Actæonella cylindracea* Stol.,
Cinulia (*Avellana*) *ampla* Stol.,
,, (*Avellana*) *elongata* Guér.,
,, (*Eriptycha*) *globata* Stol. (found near the top of the Trichinopoly stage; often mis-spelt "*Euptycha*"),
,, ,, *oviformis* (Forb.),
Ringicula acuta (Forb.),

Cephalopoda—

Ut. Ar. *Nautilus huxleyanus* Blanf.,
Ar. ,, *lentiformis* Stol.,
Cymatoceras cf. *saussureanum* Pict. (species found in the Gault of middle Europe),
,, aff. *atlas* Wh. ("*Nautilus elegans*" of Blanford and Stoliczka; species found in the Cenomanian of middle Europe and the U. S. A.),
Gaudryceras varagurense Kossm.,
,, *politissimum* Kossm. (found in New Zealand),
Tetragonites epigonus Kossm. (found in Madagascar, New Zealand, Antarctica and S. Patagonia),
Heteroceras indicum Stol. (allied to or identical with *H. polyplocum* Roem. from the Upper Senonian of north Germany, and very close to *H. saxonicum* (Schlut.) from the Upper Turonian of Germany),
Baculites aff. *bohemicus* Fritsch (species found in the Turonian of Bohemia),
Placenticeras tamulicum Blanf. (allied to *P. syrtale* Mort. of Europe and N. America, and to *P. placenta*, var. *intercalare* Meek of N. America and elsewhere, both Lower and Middle Senonian; it is also close to *P. subkaffrarium* Spath of the Zululand Senonian),
Peroniceras dravidicum Kossm. (found in the Albian of Zululand and in the Cameroons; related to *P. subtricarinatu* (d'Orb. from the Lower Senonian of Europe),
Schloenbachia serratocarinata (Stol.) (related to *S. germari* Reuss from the Turonian of Europe),
Scaphites brahminicus Stol. (related to *S. geinitzi* d'Orb. from the Turonian of Europe),
,, *simularis* Stol.[1]
(?)*andurensis* (Stol.),
(?)*idoneus* (Stol.),
Holcodiscus paravati (Stol.),
,, *theobaldianus* (Stol.),
,, *recurrens* Kossm.,
,, *sparsicostatus* Kossm.,
,, *pachystoma* Kossm.,

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[1] C. A. Matley, *Rec.* LXI, 339 (1928).

Cephalopoda—*contd.*

Kossmaticeras [*Madrasites*] *bhavani* (Stol.) (found in the Albian and Senonian of Zululand; doubtfully in New Caledonia; a veriety in Antarctica),

,, ,, *buddhaicum* (Kossm.) (allied to *K. cumshewænse* of the Antarctic, California and New Caledonia),

Pachydiscus caju (Stol.) (related to *P. peramplus* Mant. from the Turonian of Europe and elsewhere in both the Atlantic and Pacific areas),

,, *anapaudiensis* (Stol.) (also related to *P. peramplus* Mant.),

,, *jimboi* Kossm. (related to *P. peramplus* Schmidt, non Mant. from the Turonian of Saghalin),

,, *koluturensis* (Stol.) (related to *P. sutneri* Yok. from Japan),

,, *cricki* Kossm.,

Puzosia sugata (Forb.) (found in the Senonian of Zululand; related to *P. damesi* (Jimba from Japan),

,, *gaudama* (Forb.) (found in Madagascar and Japan and perhaps in New Caledonia; identical with *P. hernensis* (Schlut.) from between the Turonian and Senonian of Germany),

,, *indopacifica* Kossm.

Crustacea—

?*Neocarcinus* sp.

Ut.=found also in the Utatur stage.
Ar.= ,, ,, , Ariyalur ,,
Ni = ,, ,, Niniyur ,,

From this stage also Mr. L. R. Rao has identified the Radiolariæ, *Cenosphæra*, *Staurosphæra*, *Odontosphæra*, *Xiphostylus*, *Rhopalastrum*, *Carposphæra* (?), and *Lithocampé*.[1]

The Cephalopoda are comparatively poorly developed, only 30 species having been identified; the *Lytoceras*, *Turrilites*, *Hamites*, *Schlœnbachia*, *Pervinquierea* and *Acanthoceras* of the Utatur are wanting or much reduced in numbers, and have given place to *Holcodiscus* and *Pachydiscus*. The Trichinopoly assemblage seems to have come for the most part from two different horizons, the lower, exposed at Garudamangalam, representing all but the lowest portion of the Turonian, and characterised by ammonites related to the widespread *Pachydiscus peramplus* and by *Cardium* (*Protocardia*) *hillanum*, the upper, exposed at Varagur and belonging to the Lower Senonian, with *Placenticeras tamulicum* and *Heteroceras indicum*.

ARIYALUR STAGE.

Extent and composition.—The name of the Ariyalur stage of the south Indian Cretaceous is derived from the town of that designation situated nearly in the middle of the comparatively large expanse of Ariyalur beds in the Trichinopoly district. The country occupied by the beds of this stage is much covered with cotton soil, and exposures are even rarer than they are in the case of the two lower subdivisions.

The Ariyalur beds are more arenaceous than those of the two lower groups and more uniformly bedded, consisting principally of white unfossiliferous sands and grey argillaceous sands with casts of small fossils, in thick homogeneous beds. Beds of calcareous grit and nodular calcareous shales are found towards the base of the group, constituting a highly fossiliferous zone; above this comes a considerable thickness of deposits in which fossils are rare or wanting but include some interesting remains of a *Megalosaurus* in one of the beds. These two sub-stages are parallelled in the rocks of the same age in the Pondicherry area, where, however, the upper has yielded a copious fauna. Conglomerates are of rare occurrence in the Ariyalur stage, though a coarse bed is found in places near the base. Except in the vicinity of the southern boundary, there is but little irregularity in the bedding of the sediments. The constituents of the beds were derived chiefly from the metamorphic rocks; contributions came from the granitic band to the south and a portion of the sediment must have been furnished by the waste of the older stages, especially the Utaturs.

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[1] *Journ. Roy. Micros. Soc.*, Vol. LII, 357-361 (1932).

The above description of the lithological characters belongs to the beds near Ariyalur, but is to a great extent applicable also to the rocks seen near Vriddhachalam and Pondicherry. In both these localities the Ariyalur deposits are represented chiefly by sands or sandy clays, with beds of arenaceous limestone or calcareous sandstone at the base of the group; in Vriddhachalam the area as a whole is largely without fossils. There is some obscurity concerning the mutual relationship of the beds belonging to the Ariyalur stage in the Trichinopoly area, and this difficulty is complicated not only by the concealment of so much of the group beneath superficial accumulations, but also by the circumstance that there is in many places an apparent passage up from the Trichinopoly stage into the Ariyalur, the rocks being similar in mineral character near the junction and many of the fossils ranging from one group to the other; it is at the same time to be admitted that some of the fossils supposed to have been procured from the Trichinopoly stage, may really have been collected from the Ariyalur, and *vice versa*.

In the eastern portion of the Trichinopoly tract, the area occupied by the Ariyalur beds has been estimated at about 200 square miles, or more than that covered by the two lower subdivisions together, but this includes the area of the Niniyur Beds which were at first classed as a sub-stage of the Ariyalur. The lower fossiliferous zone is found resting upon the Trichinopoly beds to the west. Although in some of the more central sections there appears to be a passage from one to the other, the younger stage, both to the north and south, overlaps the older, and there is in places a visible unconformity; such a relationship also makes it easier to understand the very rapid diminution in thickness of the Trichinopoly beds in a northward direction on the supposition that they had suffered partial denudation in pre-Ariyalur times. The great bulk of the Ariyalur outcrop in the two more southerly tracts of Trichinopoly and Vriddhachalam appears to consist of the upper portion of the formation, composed of thick sands with but few determinable fossils.

Although the combined thickness of the Ariyalur and Niniyur groups can be estimated with a nearer approach to probability than in the case of the two lower stages, the estimate is still far from precise. The dip of the beds is very low rarely exceeding 2° or 3°, the general inclination being northeast. In the Trichinopoly tract the two stages in all probability do not exceed 1,000 feet, and the total thickness in the Pondicherry area has been estimated by Dr. Warth to be about 900 feet; in the intermediate area of Vriddhachalam the beds appear to be much thinner. A very small outlier of Ariyalur beds occurs close to the coast ten miles north of Pondicherry, and another still smaller three miles farther north.

Lower and upper boundaries.—As already partly noticed, the Ariyalur beds overlap on to the Utaturs for a distance of rather more than two miles in the northern portion of the Trichinopoly area and, still farther north, were deposited directly on the gneiss. They also rest on the gneiss throughout the whole breadth of their outcrop in the south of the Trichinopoly area as well as in the Vriddhachalam tract; in the Pondicherry tract they probably do the same but the boundary is completely concealed beneath the Pleistocene Cuddalore Sandstone to the west and east and by recent alluvium to the north and south. In the northeast of the Trichinopoly area the Ariyalurs disappear beneath a narrow belt of Niniyur strata which intervenes between them and the unconformable Cuddalore Sandstone; farther south there is no record of the presence of the Niniyurs; and the Ariyalurs are, presumably, directly overlain by the Cuddalores. Throughout the Vriddhachalam area the Ariyalurs disappear eastwards beneath the Cuddalore beds.

Mode of Accumulation.—The Ariyalur beds appear to have been deposited mostly in a tranquil sea of small depth, although the deposits are less characteristically littoral than those of the Trichinopoly stage, and the evidence of the vicinity of land afforded by the occurrence of fossil wood is less abundant.

General character of the fauna.—The invertebrate fauna of the Ariyalur exceeds in richness even that of the Utatur beds, about 420 species having been detected. As in the Trichinopoly stage, gastropods predominate; there is an abundance especially of carnivorous prosobranchiate forms (Streptoneura) which, as is well known, appear to replace the Cephalopoda of the older periods in Tertiary and Recent seas. The Cypraeidæ and Volutidæ are richly represented. Lamellibranchs are not much less numerous, but the cephalopods are distinctly subordinate; the most important of the latter are the Upper Senonian *Pachydiscus* and *Baculites*.[1] The most characteristic differential feature of the third of the four Cretaceous stages is the abundance of Bryozoa and echinoderms. Amongst the Vertebrata the only important representative is a *Megalosaurus*, of which a tooth was found at Kallamedu (Cullmoad) in the upper part of the stage, together with a number of bones which, however, could not be extracted in a sufficiently perfect state for determination.[2] The tooth closely resembles that of *M. bucklandi*, found in the Stonesfield Slate and Portland Oolites of England. Assuming the correctness of the determination, the occurrence of this genus in the Upper Cretaceous of India is of peculiar interest, because in Europe it ranges from the Lias and not above the Wealden (Neocomian). Bones of both theropodous and stegosaurian dinosaurs have recently been observed by Professor S. Iyengar[3] and by Dr. Matley.[4] Dr. Matley's specimens also came from Kallamedu near the base of the upper sub-stage of the Ariyalurs (Blanford's middle subdivision, of Upper Senonian age), but were too friable to be extracted.

Subdivision and faunas in the Pondicherry area.—The Ariyalur outcrop of Pondicherry has been examined and subdivided in more detail, both stratigraphically and palæontologically, than the tracts in Trichinopoly and South Arcot, and will stand first for consideration. The area occupied by these beds in Pondicherry extends from Valudayur for about nine miles to the northeast and is less than four miles broad. Their junction with any older formation, except with the Nerinea stage, is invariably concealed, and the country north and south is covered with alluvium. The western boundary is hidden beneath the Cuddalore sandstones of Tiruvakkarai (Trivicary).

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[1] F. Kossmat. *Rec.* XXVIII, 40-41 (1895).

[2] R. Lydekkar. *Rec.* X, 41 (1877); Mr. L. R. Rao has recently identified a cervical vertebra as that of a megalosaurid (*Amer. Journ. Sci.*, Vol. XXIV, pp. 221-224, Sept., 1932).

[3] *Half-yearly Journ. Mysore Univ.*, Vol. 1, No. 2, July, 1927, pp. 153-157.

[4] *Rec.* LXI, 337 (1928).

This very imperfectly exposed stage in the Pondicherry area has been subdivided by Dr. H. Warth into five horizons[1] each of which has a general but very gentle dip towards the southeast. The general lithological character of all the beds is one of sand or sandy clay, with calcareous nodules or concretions scattered throughout the whole formation.

The lowest horizon, A, consists of white sands with large nodules, followed by yellow, gravelly sands and, at the top, sandy clays with large botryoidal calcareous concretions. The only signs of life are some annelid burrows found in the nodules and concretions of the lowest and highest layers.

From the next horizon, B, fossils have been obtained both from the concretions and from the sandy matrix, while horizon C has yielded an important cephalopod fauna. Horizons B and C, each containing much the same fossils, together with the unfossiliferous Horizon A, together constitute what are known as the Valudayur beds, which were at first erroneously included in the Utatur.

Horizon D is characterised by a continuous bed of sandy shale, several feet thick and full of the casts of shells, including that of the lamellibranch *Trigonoarca galdrina*, and numerous small fish teeth; the shell casts are composed of a rich, black phosphate, many of the concretions being likewise strongly phosphatic. The latter contain from 56 to 59 per cent. of calcium phosphate and have been exploited commercially, but the accompanying high calcium carbonate content (16-20 per cent.) handicaps their use for the manufacture of superphosphate; the low ridge east of Valudayur has been estimated to contain about 8 million tons of nodules or concretions within a depth of 200 feet.[2] Horizon E, not conspicuously distinguishable from D, is rich in nodules of shell limestone and is not without phosphatic concretions; this shell limestone has been very largely used for building purposes, and the various fossils of the horizon can be studied in section in the walls and pavements of Pondicherry town. The coral *Cyclolites filamentosa* is especially prominent and characteristic; *Exogyra ostracina*, a lamellibranch widespread in the Campanian of Europe, is also common. Horizons D and E constitute a single palæontological sub-stage to which Kossmat has given the name of "Trigonoarca Beds".

Blanford divided what he called the Ariyalur stage of Trichinopoly into three sub-stages: (i) a lower fossiliferous group; (ii) a middle, almost unfossiliferous group; and (iii) an upper fossiliferous group of very limited distribution (now separated off as the Niniyur stage), and has roughly sketched their geographical limits in his text though not on his map. This classification in all probability corresponds more or less approximately with the threefold grouping originally applied to the Pondicherry succession and readopted in this work. It is, for instance, almost certain that the Valudayur sub-stage of Pondicherry is present at the Trichinopoly localities of Kallakkudi and Karapadi, which are situated on rocks just above the upper boundary of the Trichinopoly stage. Similarly the Trigonoarca beds of the Pondicherry area are closely matched by occurrences at the villages of Ariyalur and Otacod. The beds at Kallamedu are also assigned to the Trigonoarca subdivision. As already explained, the uppermost of the three groups in each case—the Niniyur of Trichinopoly or its equivalent the

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[1] M. S. Krishnan. *Rec.* LXX, 421 (1936).

[2] *Rec.* XXVIII, 15 (1895).

Nerinea of Pondicherry—is best regarded as a separate stage and not as part of the Ariyalur stage. The table on pp.1220-1 shows the classification of the Ariyalur beds ; while the fauna found therein is as follows :[1]

Fossils.	*Valudayur beds.*	*Trigonoarca beds*	*Remarks.*
Anthozoa—			
Cyclotites conoidea Stol.	*		
,, *fæcata* Stol.	*	*	
,, *filamentosa* Forb.	*		
,, *orbicula* Stol.	*		
Echinoidea—			
Hemiaster pullus Stol.		*	
,, *tamulicus* Kossm.		*	Related to *H. soulieri* Fall. from the Senonian of France.
,, *rana* (Forb.)		*	Forbes' "*Brissus rana.*"
,, *sexangulatus* d'Orb.		*	
Stigmatopygus elatus (Forb.)	*		Abundant. Forbes' "*Nucleolites (Cassidulus) elatus*", and equivalent to *Cyrtoma herscheliana* McClell),
Vermes—			
Serpula filiformes Sow.	*		Found in the Upper Cretaceous of Europe.
Ditrupa(?) *longissima* Forb.	*		
Bryozoa—			
Lunulites sp.	*		
Brachiopoda—			
Terebratula arabilis Forb.		*	
,, *biplicata* Sow., var.		*	
Tr. Ar. ,, *karapaudensis* Stol.			
Lamellibranchiata—			
Anomia sp.	*		
Alectryonia ungulata (Schloth.)	*	*	A widespread form, found in Baluchistan, Assam, Europe, N. Africa, Palestine, 'Oman, Madagascar, Portuguese E. Africa, etc.
Exogyra ostracina (Lam.)	*	*	Found in the Upper Cretaceous of Europe.
Tr. *Pinna arata* Forb.	*		
Ut. ,, *laticostata* Stol.	*		
Modiola polygona d'Orb.	*		
,, *flagellifera* Forb.,	*		Allied to *M. flagellifera* Zitt. (non Forb.) from the Senonian of the Gosau.
Plicatula septemcostata Forb.		*	
Spondylus lamellosus Kossm.		*	

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[1] The following fossils are recorded from Pondicherry but do not figure in Kossmat's list : *Gastrochaena aspergilloides* (Forb.), *Glycimeris* (*Axinea*) *leviculus* (Stol.), *G.* (*A.*) *cardioides* (d'Orb.), *Pinna consobrina* d'Orb., *Gervillia solenoides* Defr., *Cancellaria* (*Euclia*) *breviplicata* (Forb.), *C.* (*E.*) *camdeo* (Forb.), *Cerithium sphaeruliferum* Forb., *Dentalium* (*Antalis*) *arcotinum* Forb., and *D.* (*Fustiaria*) *paroulum* Stol., and the fishes, *Sphaerodus rugulosus* Eg., *Corax pristodontus* Ag., *C. incisus* Eg., *Otodus marginatus* Eg., *O. basal* Eg., *O. nanus* Eg., *O. minutus* Eg., *O. divergens* Eg., *Lamna* (*Oxyrhina*) *triangularis* Eg., *Odontaspis constrictus* Eg., *O. oxyprion* Eg., *Lamna complanata* Eg., *L. sigmoides* Eg. ; some of these are found also in the Trichinopoly district (*Q. J. G. S.*, Vol. I, 164-171 (1845)).

Fossils.	*Valuda-yur beds.*	*Trigono-arca beds.*	*Remarks.*
Lamellibranchiata—*contd.*			
Tr. *Spondylus calcaratus* Forb.		*	
,, *ariyalurensis* Stol.		*	
Ut. *Cardium* (*Protocardia*) *bisectum* Forb.	*	*	
Trigonoarca galdrina (d'Orb.)	*	*	
Tr. ,, *abrupta* (Forb.)	*	*	
Parallelodon [*Macrodon*] *japeticum* (Forb.).	*	*	Wilcken's genus "*Norden-Kjöldia*".
Pteria (*Meleagrina*) *nitida* (Forb.)	*		
Glycimeris [*Axinea*] *subauriculatus* (Forb.).,	*		
Yoldia striatula (Forb.)	*		Found in the Upper Senonian of Vancouver and in the Upper Cretaceous of Portuguese E. Africa.
Ut. Ni. *Lucina fallax* Forb.	*		
Cardium (*Acanthocardium*) cf. *pullatum* Stol.	*		
Tapes (*Icanotia*) *elicita* Stol.	*		
Tellina pondicherriensis Forb.	*		
(*Arcopagia*) *forbesiana* Kossm.	*		
Tr. *Solen* (*Pharella*) *delicatulus* Stol,	*		
,, ,, *obscurus* (Forb.)	*		
Tr. ,, (*Siliqua*) *limatus* Stol.	*		
Hippagus æmilianus Stol.		*	
Cyprina [*Arctica*] *cristata* Stol.		*	
Tr. *Panope* ["*Panopæa*"] *orientalis* Forb.	*	*	
Pholadomya lucerna Stol.	*	*	Found in the Upper Cretaceous of Portuguese E. Africa; cf. *P. caudata* Roem. from the European Senonian.
,, *connectans* Forb.			
Ceromya subsinuata (Forb.)	*		
Thracia [*Corimya*] *pertusa* (Stol.)	*		
Tr. *Cuspidaria* [*Neæra*] *mutua* (Stol.)	*		
Tr. *Corbula parsura* Stol.	*		Found in the Senonian of W. Africa.
,, cf. *striatuloides* Forb.	*		

Fossils.	*Valudayur beds.*	*Trigonoarca beds.*	*Remarks.*
Lamellibranchiata—*contd.*			
Arca (*Scapharca*) *clellandi* Forb.	*		Stoliczka's "*Anomalocarda* (*Scapharca*) *clellandi*".
Ar. Ni. *Nucula indefinita* Forb.	*		
Ar. *Trigonia orientalis* Forb.	*		
Ni. *Cyprimeria obesa* (d'Orb.)		*	
Thetironia ignobilis Stol.	*		Casts only.
Anatina [*Cercomya*] *arcuata* Forb.	*		Found in the Upper Campanian of Pondoland.
Tr. *Poromya lata* Forb.	*		
Clavagella semisulcata Forb.	*		
Scaphopoda—			
Dentalium (*Antalis*) *arcoticum* Forb.	*		
Tr. ,, ,, *crassulum* Stol.	*		
(*Fustiaria*) *parvulum* Stol.	?		
Gastropoda—			
Cinulia (*Eriptycha*) *larvata* Stol		*	
Ringicula labiosa (Forb.)	*	*	
Actæon curculio (Forb.)	*		
Actæonina columnaris Stol.	*		
Tr. *Bullina cretacea* (d'Orb.)	*		
Tr. ,, *alternata* (d'Orb.)	*		
Delphinula (?) *rotelloides* (Forb.)	*		
Ut. Tr. *Solariella radiatula* (Forb.)	*		
Teinostoma cretaceum (d'Orb.)	*		
Trochus arcotensis Forb.	*		
Astralium (*Uvanilla*) *rajah* (Forb.)	*		
Ut. Tr. *Phasianella incerta* Forb.	*		
Nerita (*Otostoma* or *Desmieria*) *divaricata* d'Orb.		*	
Helcion corrugatum (Forb.)	*		
Ar. *Acmaea* [*Tectura*] *elevata* (Forb.)	*		
Lunatia pagoda (Forb.)	*	*	Stoliczka's "*Auspira pagoda* Forb.".
Ar. *Eulima antiqua* Forb.	*		
Ar. *Vermetus* (*Vermiculus*) *anguis* Forb.	*		

Fossils.	*Valudayur beds.*	*Trigonoarca beds.*	*Remarks.*
Gastropoda—*contd.*			
Turritella warthi Kossm.	*		Related to *T. ventricosa* Forb., and very similar to *T. quadricincta* Goldf. from the German Senonian.
,, (*Torcula*) *pondicherriensis* Forb.	*	*	
,, (*Zaria*) *ventricosa* Forb.	*		
Ut. Tr. ,, ,, *breantiana* d'Orb.		*	
Cerithium arcotense Stol.	*		
,, *karasurense* Kossm.		*	
Tr. ,, (?*Exelissa*) *scalaroideum* Forb.	*		
Trichotropis sp.		*	
Tr. *Pollia pondicherriensis* (Forb.)	*		
,, *fluctuosa* (Forb.)		*	
Mitreola citharina (Forb.)	*		
Hindsia eximia Stol.	*		
Volutocorbis muricata (Forb.)	*	*	
Athleta (*Volutocorbis*) *radula* (Forb.)	*	*	The earliest known *Volutocorbis.*
Tr. ,, *purpuriformis* (Forb.)	*		
Ficulopsis pondicherriensis (Forb.)	*		
Melo pyriformis (Forb.)	?	*	
Tr. *Gosavia indica* Stol.	*	*	
Ar. *Ancilla* [*Dipsaccus*] *vetusta* (Forb.)	*		
Transovala globulina (Stol.)		*	
Tr. *Protocypraea kayei* (Forb.)		*	
Tr. *Eocypræa newboldi* (Forb.)		*	
,, *cunliffoi* (Forb.)		*	
Tr. *Calyptraphorus palliatus* Forb.	*	*	
Tr. *Aporrhais securifera* (Forb.)	*		
Tr. *Pugnellus uncatus* (Forb.)	*	*	
Crustacea—			
Neocarcinus sp.			

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[1] See L.R. Cox. *Pal. Ind.* New Ser., Vol. XV, Mem. viii, 198 (1930).

Fossils.	*Valudayur beds.*	*Trigonoarca beds.*	*Remarks.*
Pisces—			
Otodus sp.		*	
Fossil wood . . .		*	

In addition to the above, the following taken from Stoliczka's lists with modifications have been found in the Ariyalur stage of the Trichinopoly and Vriddhachalam tracts :

Italia sp.,
Lagena sp.

Vermes—
Serpula cordialis Schloth. (A European form, very common in the Upper Plaener of Saxony).

Anthozoa—
Caryophyllia arcotensis Stol.

Echinoidea—
Hemiaster tuberosus Stol.,
,, *indicus* Stol.,
,, *cristatus* Stol.,
Epiaster nobilis Stol.,
Cardiaster orientalis Stol.,
Catopygus sulcatellus Stol.,
Botriopygus sp.,
Cassidulus oldhamianus Stol.,
,, *crassus* Stol.,
Echinobrissus (*Nucleolites*) *pullatus* (Stol.),
Echinoconus placentula Stol.,
,, cf. *conicus Breyn.* (a well known European Senonian form),
Holectypus sp.,
Salenia arcotensis Stol.,
Micropedina sphaeroides Stol.,
Diadema (*Pseudodiadema*) *subangulatum* Stol.,
Cidaris sceptrifera Mant. (widespread in the Senonian of Europe),
Orthopsis similis Stol.,

Ophiuroidea—
Ophiura(?) *cunliffei* Forb. (at Vriddhachalam and perhaps also in the Valudayurs of Pondicherry),

Crinoidea—
Marsupites milleri Mant. (Found in the Senonian of Europe),
Marsupites cf. *ornatus* Miller (found in the Chalk of Europe),
Pentacrinus sp.

Bryozoa—
Cellepora prona Stol. (*Cellepora*, *Membranipora*, *Eschara*, *Biflustra* and other forms are regarded by some as synonymous with the genus *Onychocella*).
,, *puncticulata* Stol.,
,, *insipiens* Stol.,
,, *missilis* Stol.,
,, (*Celleporaria ?*) sp.

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[1] From Comarapalliam come several forms not found elsewhere, and a few which are recovered from the Niniyur beds ; these have all been included in the list which follows :

Bryozoa—*contd.*
Membranipora auriculata Stol.,
Eschara optabilis Stol.,
,, *porigera* Stol.,
Biflustra cingulata Stol.,
Escharifora ortiva Stol.,
,, *ominosa* Stol.,
Discopora obtecta Stol.,
Escharinella discors Stol.,
Lunulities annulata Stol.,
Cellaria (*Salicornaria*) *lauta* Stol.,
Planicellaria oculata d' Orb. (found in the Senonian of France),
Truncatula sp.,
Idmonea sp.,
,, (*Crisina*) sp.,
Ceriopora dispar Stol.,
Heteropora tamulica Stol.,
,, (*Zonopora*) *indica* Stol.,
Proboscina radiolitorum d'Orb. (found in the Turonian of Europe),
,, *angustata* d'Orb. (found in the Cretaceous (? Cenomania),
Entalophora lineata Beiss. (found in the Senonian of France),
,, *pavimentata* Stol.

Brachiopoda—
Crania ignabergensis Retz. (Found in the Senonian and Danian of Europe),
Rhynchonella ariyalurensis (" *arrialoorensis* ") Stol.,
,, *crenifera* Stol.,
,, *nutans* Stol.
Terebratula (*Rectithyris*) *subdepressa* Stol.,
Tr. ,, (*Gibbithyris*) *subrotundata* Sow, var. *subundate* Stol. (Species found in Turonian and Senonian of Europe),
,, (*Gibbithyris*) *grandis* Sahni,
,, *biplicata* Sow., var. *karapaudiensis* Stol.,
,, cf. *carteri* Davd. (*forma typica* found in the Turonian and Senonian of Europe),
Kingena granulifera Stol.,
,, *asperulina* Stol.

Lamellibranchiata—
Gasioochaena aspergilloides (Forb.),
Corbula exulans Stol.,
Poromya globulosa Forb. (rare ; allied to the Maestrichtian *P. papyracea* of Europ),
Tagelus albertinus (d'Orb.) (recorded in the Upper Cretaceous of Portuguese E. Africa),
Tellina scitulina Stol.,
,, (*Tellinoides*) *primula* Stol.,
,, (*Angulus*) *undata* Stol.,
,, (*Linearia*) *sculptilis* Stol.,
Meretrix (*Cytherea*) *garudana* (Stol.),
,, ,, *crassula* (Stol.),
,, (*Callista*) *sculpturata* Stol. ("*Cytherea*"),
,, ,, *minutula* Stol. (" ,, "),
Tr. ,, ,, *vagrans* Stol. (" ,, "),
Tr. ,, (*Caryatis*) *telugensis* Stol. (" ,, "),
Tr. *Cyprimeria analoga* (Forb.),
Astarte (*Eriphyla*) *diversa* Stol.,
Tr. ,, ,, *lenticularis* (Goldf.)[1] (found in the Senonian of Pondoland and Zululand),

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[1] C. A. Matley. *Rec.* LXI, 340 (1928).

Lamellibranchiata—*contd.*

Tr. *Venericardia obtruncata* Stol.,
Cardium (*Trachycardium*) *exulans* Stol.,
,, (*Protocardia*) *delicatulum* Stol.,
Caprotina cf. *cenomanensis* (d'Orb.) (species found in the Cretaceous of France),
Radiolites mutabilis (Stol). (according to Douvillé, this rudistid is a *Bournonia* or *Biradiolites* of the *Bournoni* group.[1])
Mutiella exigua Stol.,
Lucina undata Stol.,
Tr. ,, (*Myrtea*) *arcotina* Stol.,
,, ,, *dentigera* Stol.,
Crassatellites (*Crassatellia*) *macrodonta* (Sow.). (Found in the Cardita beaumonti beds of Sind and in the Upper Cretaceous of Europe),
Tr. *Trigonia scabra* Lam. (found in the Upper Cretaceous of Europe),
,, *indica* Stol.,
,, *minuta* Stol.,
,, *crenifera* Stol.,
Tr. ,, *semiculta* Forb.[2],
Yoldia obtusata Stol.,
,, *scaphuloides* Stol.,
Nucula tamulica Stol.,
,, *crassicula* Stol.,
Glycimeris (*Axinea*) *subplanatus* (Stol.),
,, ,, *leviculus* (Stol.),
,, *altiusculus* (Stol.),
Trigonoarca brahminica (Forb.) (closely allied to *T. matheroniana* d'Orb.),
Arca (*Scapharca*) *ponticeriana* d'Orb.,
Lithodomus tumidula Stol.,
Modiola nitens (Forb.),
Tr. ,, *typica* (Forb.)[3]
Mytilus ariyalurensis ("*arrialoorensis*") Stol.,
Pteria (*Oxytoma*) *semiglobosa* (Stol.),
Septifer radiatulus (Stol.),
,, *annectans* (Stol.),
Inoceramus balticus Bohm. (Found in the Senonian of Europe; originally identified erroneously as *I. cripsi* or *I. cripsiamis* Mant.[4]),
,, *simplex* Stol.,
Pedalion validum (Stol.) Stoliczka's ("*Melina valida*"),
Lima (*Plagiostoma*) *nudata* (Stol.), (Stoliczka's "*Radula Plagiostoma*) *nudata*",
,, ,, *scabricula* (Stol.) (Stoliczka's "*Radula* (*P.*) *scabricula*"),
,, (*Ctenoides*) *tecta* Goldf. (found in the Upper Cretaceous of Europe),
,, ,, *scaberrima* (Stol.) (Stoliczka's "*Radula* (*C.*) *scaberrima*"),
,, (*Acesta*) *obliquistriata* Forb. (found in the upper Campanian of Pondoland),
Pecten raduloides Stol.,
,, (*Chlamys*) *asperulinus* Stol.,
,, (*Vola; Janira*) *quinquecostatus* Sow.,
Tr. *Pecten* (*Camptonectes*) *curvatus Gein.* (Found in the Cenomanian, Turonian and Senonian of Europe, but confounded in some cases with P. *virgatus* Nilss.),
Amusium illustre Stol.,
,, *sulcatellum* Stol.,
,, (?) *membranaceum* (Nilss.) (Found in the Turonian of Europe),

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[1] *Mem. Soc. Géol. France*, Pal XVIII, Fasc. 1 (1910),

[2] *Rec.* LXI, 340 (1928).

[2] *Rec.* LXI, 340 (1928).

[4] *Rec.* LVI, 265 1924).

Lamellibranchiata—*contd.*

Plicatula striatocostata Stol.,
,, *instabilis* Stol.,
Spondylus sulcatellus Stol.,
Ostraea orientalis Douv. (Stoliczka's "*Q. acutirostris* Nilss.")[1]
,, *acutirostris* Nilss.,
,, *telugensis* Stol.,
,, *zitteliana* Stol.,
Alectryonia cupelloides Stol.,
,, *pectinata* (Lam.) (widespread and characteristic in the middle Senonian-Santonian of Europe, and found in N. Africa, America and elsewhere),
,, *arcotensis* Stol.,
Gryphaea ariyalurensis ("*arrialoorensis*") Stol. (closely resembles to the European *G. scaniensis* Coq.),
Gryphaea ariana Stol.,
,, *vesicularis* (Lam.) (a widespread form very characteristic of the Upper Senonian and Campanian of Europe; found also in Asiatic Russia, Syria, N. Africa, Portuguese E. Africa, N. America, etc.),
Exogyra tamulica Stol.,
Anomia variata Stol.

Gastropoda—

Angystoma cretaceum Stol.,
Macrocyclis carnatica Stol.,
Tr. *Pugnellus granuliferus* Stol.,
Aporrhais ariyalurensis ("*arrialoorensis*") Stol.?
Tr. *Aporrhais tegulata* Stol.,
Tr. *Alaria papilionacea* Goldf.,
,, *acicularis* Stol.,
Palliatus Stol.,
Cypræovala carnatica (Stol.), (Stoliczka's "*Cypraea* (*Luponia*) *carnatica*"),
Pustularia anomala (Stol.), (Stoliczka's "*Cypraea* (*Epona*) *anomala*"),
Erato varagurensis ("*veraghoorensis*") Stol.,
Oniscia (*Morum*) *costellata* Stol.,
Cythara cretacea Stol.,
Tr. *Scaphella* (*Fulguraria*) *elongata* (d'Orb.) (perhaps a *Volutoderma*; *Scaphella elongata* found in the Cenomanian and Turonian of Europe),
Volutilithes septemcostata (Forb.),
Lyria crassicostata Stol. (a variety of this species is found in the Maestrichtian of Omah)
Lyria granulosa Stol. (provenance uncertain),
Turricula ariyalurensis ("*arrialoorensis*") Stol.,
Fasciolaria carnatica Stol.,
,, *assimilis* Stol.,
Hemifusus acuticostatus Stol.,
Crysodomus (*Neptunea*) *rhomboidalis* (Zek) (a Gosau species),
Tritonium (*Nyctilochus*) *gravidum* Stol.,
Tr. *Hemifusus* (*Mayeria*) *nodulosa* Stol.,
,, *secans* Stol.,
Nassa vylapaudensis Stol.,
,, *ariyalurensis* ("*arrialoorensis*") Stol.,
Cancellaria annulata Stol.,
,, (*Euclia*) *breviplicata* (Forb.),
,, ,, *intercedens* Stol.,
,, ,, *camdeo* (Forb.),

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[1] *Pal. Ind.* New Ser. Vol. X, Mem. 3, p. 68 (1929).

Gastropoda—*contd.*

Itruvia globoides Stol.,
Cerithium (*? Fibula*) *detectum* Stol., (rare),
Tr. ,, (*Campanile*) *inauguratum* Stol.,
,, *limbatum* Stol.,
,, *carnaticum* Stol.,
Tr. ,, *vagana* Stol.,
,, *sphæruliferum* Forb.,
,, *lassulum* Stol.,
,, *trimonile* Mich. (common in the Albian of France),
Potamides (*Sandbergia*) *trichinopolitense* (Forb.) ?
,, ,, *crispicans* (Stol.),
Turritella ("*Torcula*") *gemina* Stol.,
,, (,,) *dispassa* Stol.,
Tr. ,, ("*Zaria*") *multistriata* Reuss (found in the Turonian of Europe),
,, *contumescens* Stol.,
,, ("*Zaria*") *tritira* conr.,
Scalaria (*Scala*) *subturbinata* d'Orb. (found in the Senonian of Maestricht),
,, ,, *striatocostata* Müll. (found in the Senonian of France),
Burtinella concava Sow. (found in the English Chalk),
Thylacodes lamellosa Stol. (identified in the Maestrichtian of Oman),
Xenophora carnatica Stol.,
Solarium kurribiemse Stol.,
,, *karapaudiense* Stol.,
Ut. ,, *vylapaudiense* Stol.,
Littorina undata Stol.,
,, *crassitesta* Stol.,
Rissoina acuminata Müll. (found in the Senonian of France),
Keilostoma subulatum Stol.,
Tr. ? *Euchrysalis gigantea* Stol., (see remarks),
Tylostoma bulimoides Stol.,
Tr. *Amauropsis pannucea* Stol.,
,, *ariyalurensis* Spengl.,
Euspira rotundata (Sow.) (found in the Cenomanian of England),
Ut, Tr. *Gyrodes pansus* Stol.,
Tr. ,, *tenellus* Stol.,
Mamilla carnatica Stol.,
Naticina ornata Stol.,
Velutina orientalis Stol.,
Amplostoma auriforme Stol.,
Acmaea (*Tectura*) *footeana* (Stol.),
Helcion carnaticum Stol.,
Tr. *Nerita* (*Neritina*) *compacta* Forb.,
,, *carolina* Stol.,
,, *rugosissima* (Forb.).
Velates decipiens Stol.,
Vitrinella orbiculata Stol. (in the Vriddhachalam area only).
Tr. *Phasianella globoides* Stol.,
,, *conula* Stol.,
Astralium (*Lithopoma*) *intersectum* Stol.,
Monodonta (*Oxystele*) *notabilis* Stol.,
Gibbula jordoniana Stol.,
,, *granulosa* Stol.,
Euchelus ornatus Stol.,

Gastropoda—*contd.*

Trochus (*Tectus*) *tamulicus* Stol., (identified in the Maestrichtian of 'Oman),
,, ,, *junceus* Stol.,
Tr. *Calliostoma* (*Ziziphinus*) *geinitzianum* (Reuss).
Cantharidus striolatus Stol.,
Tr. *Pleurotomaria* (*Leptromaria*) *indica* Forb.,
Actaeonina obesa Stol.,
Solidula pugilis Stol.,
Actaeonella truncata (Stol.),
Trochactaeon minutus (Stol.),
Bullinula obtusiuscula Stol.,
Cinulia (*Avellana*) *scrobiculata* Stol.,
,, ,, *sculptilis* Stol.,
,, (*Ringinella*) *acuminata* Stol.,
Cylichna inermis Stol.,

Pisces—
Ptychodus latissimus Ag. (found in the Upper Greensand and Chalk of Europe),
Otodus cf. *semiplicatus* Münst. (species found in the Plaener of Germany),
Lamna (*Oxyrhina* : *Meristodon*) sp.,
Enchodus serratus Eg.

The following is a list of the cephalopods, not only from the Trichinopoly district but also from Pondicherry, the ammonoids revised by Kossmat and the nautiloids by Spengler :

		Trichinopoly.	Pondicherry.	Remarks.
	Nautiloidea—			
	Nautilus cf. *baluchistanensis* Spengl.	*	?	*N. bouchardianus* d'Orb. *pars*, and *N. clementinus* d'Orb. *pars* of Blanford.
	,, *pseudobouchardi* Spengl. .	*	?	Allied to *N. bouchardianus* d'Orb. of the European Gault.
Ut.	,, *sphaericus* Forb. . .	*		
Ut. Tr.	,, *huxleyanus* Blanf. . .	*		
Ut.	,, cf. *clementinus* d'Orb. .	*		probably a *Cymatoceras*[1]
Tr.	,, *lentiformis* Stol. . .	*		
Ut.	,, *angustus* Blanf. . .	*		
	,, *pondicherriensis* Blanf. .		?	(omitted by Kossmat),
	,, *compbelli* Meek . .	*	Val.	Lower Ariyalur ; found also in Vancouver.
	Eutrephoceras sublaevigatum (d'Orb.), var. *indica* Spengl. . . .	*	? Trig.	
	Cymatoceras valudayurense (Blanf.) .	*	Val.	
	,, *formosum* (Blanf.) .	*		
	Hercoglossa trichinopolitensis(Blanf.)	*		Found also in Borneo.
	,, *rota* (Blanf.) . .	*		
	,, *serpentina* (Blanf.) .	*		
	Carinonautilus ariyalurensis Spengl.	*		Lower Ariyalur.

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[1] L. F. Spath. *Ann. S. Afr. Mus.*, XII, 295 (1918).

	Trichinopoly.	Pondicherry.	Remarks.
Ammonoidae.—			
Phylloceras nera (Forb.) . .		Val.	Found in Antarctica, S. Patagonia and New Zealand ;[1] perhaps equivalent to P. *ramosum* Meek from the Senonian of Vancouver.
,, *decipiens* Kossm. . .		Val.	
,, *surya* (Forb.) . .		Val.	Found in the Senonian of Chile.
,, *forbesianum* (Forb.) .		Val.	Found in the Senonian of Vancouver.
Gaudryceras subtililineatum Kossm.	*		
,, *kayei* (Forb.) . .		Val.	Found in Baluchistan, Antarctica, Chile, California, Vancouver, etc.
,, *valudayurense* Kossm. .		Val.	
,, *varuna* (Forb.) . .		Val.	Found in the Senonian of Chile.
Tetragonites cala (Forb.). . .		Val.	
Pseudophyllites indra (Forb.) . .		Val. Trig.	Found in California, Vancouver. Antarctica, Madagascar, and in the Upper Senonian of Natal; cf. *P. colloti* Gross. of Europe.
Hamites indicus Forb. . . .		Val.	? *Diplomoceras*; found in the Senonian of Natal, Pondoland and Zululand.
,, *subcompressus* Forb. .		Val.	Found in the Upper Senonian of Pondoland.
,, *rugatus* Forb. . . .		Val.	Related to *H. cylindrassus* Dep. from the Upper Senonian of Europe.
,, *largesulcatus* Forb. . .		Val.	
,, *tenuisulcatus* Forb. . .		Val.	
,, *undulatus* Forb. . .		Val.	
,, *nereis* Forb. . . .		Val.	
Ptychoceras sipho Forb. . . .		Val.	
Baculites teres Forb. . . .		Val.	
,, *vagina* Forb. . . .		Val.Trig.	Recognised in the Upper Senonian of Chile; related to the European *B. anceps* Lam. and *B. occidentalis* Meek from Vancouver; a comparable form occurs in the Senonian of Portuguese E. Africa.
Baculites vagina var. *simplex* Kossm. . .	*	Val.	
,, ,, var *otacodensis* Stol. . .	*	Val.	
Sphenodiscus siva (Forb.) . .		Val.	Related to *S. ubaghsi* Gross. from the Upper Senonian of Europe, and to *S. lenticularis* Mort. from Texas.
Placenticeras tamulicum Kossm. .	*		From Sillakkudi (Shillagoody).[2]
Muniericeras blanfordianum Stol. .	*		Recognised in the Senonian of Syria.
Scaphites cunliffei Forb. . .		Val.	Related to *S. aquisgranensis* Schlüt. and *S. constrictus* Sow., from the Senonian of Europe.
,, *pavana* Forb. . . .		Val	

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[1] P. Marshall. *Trans. N.Z. Inst.*, Vol. LVI,. 961 (1926).

[2] Das Gupta. *Proc. Ind., Ass. Cult. Sci.*, p. 3, 1916 .

Ammonoidea—*contd.*

		Trichinopoly.	Pondicherry.	Remarks.
	Holcodiscus pacificus (Stol.)	*		
	,, *indicus* (Forb.)		Val.	
Tr.	,, *theobaldianus* (Stol.)	*		
	,, *pondicherrianus* Kossm.		Val.	
	,, *aemilianus* (Stol.)	*		Related to *H. gemmatus* Hup. from the Senonian of Chile.
	,, *kandi* (Stol.)	*		
	,, *kalika* (Stol.)	*		
	,, *madrasinus* (Stol.)	*		
	,, *karapadensis* Kossm.	*		
	Kossmaticeras (*Madrasites*) *bhavani* (Stol.)	*		
	Brahmaites brahma (Forb.)	*	Val. Trig.	Related to *B. haugi* Seun. from the Upper Senonian of France.
	,, *vishnu* (Forb.)	*	Val.	
	Pachydiscus egertonianus (Forb.)	*	Val.	Closely related to the European *P. neubergicus* Hauer.
	,, *ganesa* (Forb.)		Val.	Related to *P. neubergicus* Hauer and to the Upper Senonian *P. jaquoti* Seun.
	,, *gollevillensis* (d'Orb.)		Trig.	Found in the Upper Senonian of France and Ireland.
	,, *krishna* ("*crishna*") (Forb.)		Val.	Found in the Upper Senonian of France and Ireland.
	,, *otacodensis* (Stol.)	*		Found in the Upper Senonian of Vancouver; cf. the European *P. colligatus* Binkh.
	Pachydiscus grossouvrei Kossm.	*		Related to *P. levyi* Gross. from the Upper Senonian of France.
	,, *tweenianus* (Stol.)	*		Found in Madagascar; related forms in Vancouver, Chile and Japan.
	,, *deccanensis* (Stol.)	*		
	,, *menu* (Forb.)		Val.	
	Parapachydiscus ariyalurensis (Stol.)	*		Found in Japan; cf. the Zululand form, *P.* aff. *colligatus* Binkh.
	Desmoceras diphylloides (Forb.)	*	Val.	Related to *D. selwynranum* Whit. from the Cenomanian of Vancouver.
	,, *phyllimorphum* Kossm.	*		Related to *D. larteti* Seun. from the Upper Senonian of France.
Tr.	*Puzosia sugata* (Forb.)	*		Recognised in the Senonian of Zululand; cf. *D. damesi* Jimbo from Japan.
	Hauericeras rembda (Forb.)		Val.	Found in the Upper Senonian of Natal; cf. *P. faycli* Gross. from Europe.
	,, *gardeni* Baily	*		Found in the Upper Senonian of Natal, Japan and Vancouver and in Madagascar, New Zealand and Antarctica.

Belemnoidea.—

Belemnites sp.

The most numerous and best preserved fossils come from the Valudayurs, especially from the characteristic concretionary masses of hard, bluish or brownish fine-grained, calcareous shell-sandstone which is not unlike the "Trichinopoly marble" of the Middle stage. From a single hand specimen of this rock it is often possible to extract more than a dozen different species. The state of preservation is as a rule remarkable; not only has the shell substance survived in nearly all the fossils, but the ammonites show the pearly layer and in the other molluscan shells the original colour often remains.[1] Exposures of these beds are so limited that the supply of fossils some time ago became practically exhausted. The richest fossil horizon is the Pondicherry Horizon C. From the Pondicherry neighbourhood, and probably from the Valudayur rocks, comes the pentalocular fruit, *Pondicherria ebenaleoidea* Sahni, with its single seed in each loculus; this fruit almost certainly belongs to a dicotyledonous plant, which might well be one of the Ebenaceae or Sapotaceae, allied to the genus *Diospyros* (Ebenaceae) or to *Achras*[2] (Sapotaceae).

In the Trigonoarca beds the ammonites of the Valudayurs have become rare, the most abundant fossils in addition to *Trigonoarca galdrina* being *Turritella breantiana*, *Nerita divaricata*, several of the Cypraeidae, *Rostellaria palliata*, *Parallelodon japeticum*, *Exogyra ostracina*, *Alectryonia ungulata*, and occasional sharks' teeth (*Otodus* sp.).

Taking the Ariyalur fauna as a whole, its most prominent features are the upper Senonian species of *Pachydiscus* and *Baculites*; *Baculites vagina* is especially characteristic.

NERINEA AND NINIYUR STAGE.

The Nerinea Beds of Pondicherry, Warth's highest horizon, "F", consist of a yellow, crystalline, somewhat sandy limestone, overlain by fossiliferous sands and clays, and are characterised by cylindrical so-called "fucoid" casts which sometimes bifurcate; these casts and the foraminiferal calcareous nodules found in the same bed are much used for lime-burning. The limestone, the only continuous bed of hard rock in the Pondicherry Cretaceous is from two to five feet thick and dips generally towards the southeast, the dip-slope coinciding more or less with the ground surface. It has been traced from a point on the Usteri canal, one mile S.S.E. of Valudayur eastwards and northwards through Kadapperikuppam, Sedarappattu (Saidarampet), the vicinity of Akasampattu, a little to the south of Wattampalliam, to the bed of a large pool near Rayapuduppakkam (Royapoothoopakkam). The overlying sands and clays are nodulifeorus and one of the clay bands has yielded some shells with light-coloured phosphatic cores; among these are some very characteristic corals (*Caryophyllia arcotensis* and *Cyclolites conoidea*), *Teredo* tubes in abundance, some very large gastropods a foot or so in length, *Hercoglossa serpentina*, and remains of a turtle. The concretions in some of the higher beds are sometimes two feet in diameter. The uppermost of the Pondicherry Cretaceous beds are yellow clays with minute bivalves and are seen near Tirusitambalam and along the flank of the Red Hills.

The principal features of the Nerinea fauna are large specimens of *Nerinea* and nautiloids—including the European *Hercoglossa danica*—and vast numbers of foraminifera, especially of *Orbitoides*, filling the hard matrix of the bigger fossils;

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[1] F. Kossmat. *Rec.* XXX, 54 (1897).

[2] *Rec.* LXVI, 436 (1932).

ammonites are wanting. The following fossils have been obtained from the Pondicherry area :

Foraminifera—
    Amphistegina (?) sp.,
    Orbitoides sp.
Anthozoa—
Ar. *Cyclolites filamentosa* (Forb.) (provenance uncertain),
Ar. *Cyclolites conoidea* Stol.,
Ar. *Caryophyllia arcotensis* Stol. (including Forbes' "*Turbinoli arcotensis.*"),
Lamellibranchiata—
    Ostraea sp.,
    Teredo glomerans Stol.
Gastropoda—
    Cerithium karasurense Kossm.,
    Nerinea sp.
Cephalopoda—
Ar. *Nautilus sphaericus* Forb.,
    Aturia delphina (Forb.) (Provenance uncertain),
    Hercoglossa tamulica Kossm.,
        ,, *danica*, Schloth, var. *indica* Spengl. (*forma typica* found in Europe, Portuguese E. Africa, etc.),
        ,, *serpentina* (Blanf.).

In the Trichinopoly area the corresponding beds, known as the Niniyur stage, have been traced from Authicoodicaud, a village ten miles northeast of Ariyalur, extending northwards and eastwards as a narrow belt, two miles or less wide, up to the Vellar river and beyond, lying on the east side of Nanniyur (Niniyur) and Sendurai (Sainthoray), two localities which have furnished most of the fossils belonging to this stage. The best exposures of this stage are not those of Nanniyur itself but are to be seen northeast, east and southeast of the village of Sendurai ; elsewhere in the Trichinopoly area it crops out at Yellakudumbur (Ellaikkadambur), Nattakuli (Nattagooly), and Adanakkurichchi (Authencoorchy)[1]. As remnants of an originally much more extensive deposit, the Niniyur sediments bear evidence of having been laid down in shallow water. They overlie the unfossiliferous greenishyellow sands and clays of the higher Ariyalur sub-stage and indicate a slight post-Senonian repetition of the marine transgression which had been interrupted towards the close of the epoch represented by this sub-stage —the equivalent of the Trigonoarca beds of Pondicherry.

The lowest rock of the Niniyur stage is a gritty argillaceous limestone crowded with fossils and in places so full of corals as to merit the term, coral limestone ; the commonest fossils are species of *Gryphaea* and *Cardita*, the latter including a form comparable to *Cardita* (*Venericardia*) *beaumonti*. Under the microscope, the angularity of the quartz grains is well seen. The rock often includes small, white, irregular earthy patches of kaolin-like material, and associated with it are abundant calcareous nodules.

Towards the upper part of this basal zone, a few thin bands of nodular, crystalline, almost unfossiliferous limestone make their appearance, after which the gritty argillaceous rock gives place to a highly fossiliferous, white, compact, crystalline limestone characterised in its lower portions by pebbles of calcareous material. By far the most abundant and typical fossil in this limestone is a large

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[1] L. Rama Rao. *Pal. Ind.*, New Ser., Vol. XXI, Mem. 4, p. 2 (1936).

Lucina (Blanford's "*Crassatella*"), probably *L. percrassa* ; in addition are the large and important nautiloid, *Hercoglossa danica*, compound corals, bryozoa, lamellibranchs such as *Gryphaea*, *Cardita*, *Lima* and *Arca*, and gastropods like *Nerinea*, *Cerithium*, *Voluta* and *Turritella*. In places this limestone, including its contained pebbles and fossils, is silicified to flint. One of the most interesting features of the limestone, discovered by Professor L. Rama Rao and Dr. Julius Pia, is the occurrence therein of a large amount of algal material, especially in the pebbly varieties ; this applies to the silicified as well as to the normal type of the rock. The "pebbles" are in fact nothing but rounded patches of algae in a matrix of calcite.[1] The commonest alga is *Dissocladella savitriae* Pia, showing a marked similarity to *D. undulata* Rain. from the Cenomanian-Turonian of north Africa. In addition Dr. Pia has identified the following : *Indopolia satyavanti* Pia, (a Neomerian dasycladid), *Acicularia dyumatsenae* Pia, *Orioporella malaviae* Pia, *Palaeachlya* sp., *Parachaetetes asvapatii* Pia, *Archaeolithothamnium lugeoni* Pfend. (found in the Eocene of Spain, but not so far in the Palaeocene), *A.* aff. *provinciale* Pfend. (a species found in the Cenomanian and Senonian of southern France) and *A.* cf. *lycoperdioides* Mich. Associated with the algae are many corals, a few bryozoa and several foraminifera, the last chiefly members of the Miliolidae such as *Biloculina*, *Triloculina* and *Quinqueloculina*. At Yellakudumbur more than half the limestone is made up of algala mterial.[2]

In spite of the intimate relationship of the Niniyur beds with those of the Ariyalur stage, there is a marked contrast in the faunas of the two formations. Unfortunately these faunas have been described as one, and the following list, which is the result of an attempt to disentangle one from the other, based on localities, is subject to future correction, but the fossils have all been collected from the neighbourhood of Nanniyur and belong presumably to the Niniyur stage :

Foraminifera—
Lepidorbitoides socialis (Leym.)[3]
Anthozoa—
Stylina parvula Stol.,
Holocoenia indica Stol.,
Astrocosnia pumila Stol.,
Tr. ,, *decaphylla* Mich. (found in the Turonian of Europe)
Thamnastraea brevipes Stol.
Bryozoa—
Membranipora pedata Stol.
Lamellibranchiata—
Rocellaria sp.,
Tellina (*Tellinella*) *arcotensis* Stol.,
Meretrix (*Callista*) *laciniata* (Stol.),
,, ,, *discoidalis* (Stol.),
Cyprimeria obesa (d'Orb.),
Astarte (*Eriphyla*) *forbesiana* (Stol.),
Cardium (*Cerastoderma*) *pilatum* Stol.,

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[1] Most of the rocks of the Trichinopoly Cretaceous area, especially the limestones, have since been found to contain abundant algal remains. These are being studied by Prof. Rama Rao and his colleagues in the University of Mysore (see "*Current Science*", VII, No. 5, Nov., 1938 ; also an account of the flints from this stage by L. R. Rao and C. Prasannakumar in *Proc. Ind. Acad. Sci.*, Vol. I, sect. B, 10-18 (1934)).

[2] *Pal. Ind.*, New Ser., Vol. XXI, *Mem.* 4, p.5 (1936).

[3] Vredenburg's "*Orbitoides minor* Schlumb.", Stoliczka's "*O. faujasi* (Def.)". Found in the Sulaiman range, Tibet and the equivalent of the Niniyur Stage in Madagascar. *Rec* XXXVI, 193 (1907). *Pal. Ind.* New Ser. Vol. V, *Mem.* 3, pp. 33-34 (1916).

Corbis typica Stol.,
,, *oblonga* Stol.,
Lucina (*Codakia*) *percrassa* Stol.,
Ut. ,, *fallax* Forb.,
,, (*Cyclas*) *taeniolata* Stol., (perhaps more correctly *Sphaerium taeniolatum*)
Cardita (*Venericardia*) *jacquinoti* d'Orb. (perhaps equivalent to *C.* (*V*). *beaumonti* d'Arch.),
Crassatellites zitteliana (Stol.),
Nucula indefinita Forb.,
Ar. *Glycimeris* [*Axinea*] *altiusculus* (Stol.),
Cucullaea (?) *aequata* Stol.,
Arca (*Barbatia*) *decora* Stol.,
Lima (*Plagiostoma*) *interplicosa* Stol.,
Hemiplicatula (?) *detrita* Stol.,
Exogyra laciniata Nilss. (found in the Campanian of Europe),
Ar. *Gryphaea vesicularis* Lam.
Ostraea orientalis Douv. (provenance from the Niniyur beds uncertain; Stoliczka's *O. acutirostris* Nilss.)

Gastropoda—
Ar. *Angystoma cretaceum* Stol.,
,, *ariyalurense* ("*arrialoorense*") Stol., (said to resemble the recent *Helix nilgirica*),
Scaphella (*Scapha*) *gravida* Stol.,
Lyria formosa Stol.,
Pseudoliva subcostata Stol.,
Rapa corallina Stol.,
Tr. *Cancellaria* (*Narona*) *eximia* Stol.,
Turritella (*Torcula*) *asperata* Stol.,
,, (*Zaria*) *ventricosa* Forb. (identification very doubtful; according to Kossmat it differs greatly from the true *T. ventricosa*),
,, *elicita* Stol.,
Potamides (*Pyrazus*) *pedroanus* (White), var. *indica* Spengl. (found in the Upper Cretaceous of Brazil).
Solarium (*Climacopoma*) *arcotense* Stol. (recorded in the Danian of Tunis),
Keilostoma substriatum Stol.,
Ampullina sortita Stol.,
Euspira lyrata (Sow.), (found in the Turonian and Senonian of Europe, Palestine, etc.),
Mamilla edura Stol.,
Tr. *Solidula semen* (Forb.),

Cephalopoda—
Hercoglossa danica Schloth., var. *indica* Spengl.

Two of the most abundant fossils of the Niniyur and Nerinea faunas are closely allied to the nautiloid, *Hercoglossa danica*, and the foraminifer, *Orbitoides minor*, both characteristic of the Danian deposits of either Maestricht, Aix-la-Chapelle or the Danish island of Rugen. *Hercoglossa danica*, a species found not only in Jutland and Scania but also in the Paris basin, the south of France, Egypt, Portuguese East Africa and elsewhere, is the only cephalopod in the Niniyur beds, though three or four other nautiloids accompany it in the Nerinea fauna. The characteristically Mesozoic genera, *Inoceramus*, *Radiolites*, *Trigonia*, *Trigonoarca*, and which are abundantly represented in the Ariyalur are entirely wanting in the uppermost stage of the Coromandel Cretaceous, where the only important Mesozoic genus in addition to the *Hercoglossa* is *Nerinea*. The assignment of this stage to the top of the Cretaceous is confirmed by the presence therein of *Cardita jacquinoti*, which is either equivalent or very closely related to *C. beaumonti*, the index species of the Danian in northwest India and Persia. At the same time, no typically Tertiary forms make their appearance except some carnivorous gastropods, and these are no more numerous in proportion than they are in the stage below, although some additional forms are represented. While, therefore, the ammonite faunas of the Ariyalur beds, including the two sub-stages of the Valudayurs and Trigonoarca beds, point definitely to an Upper Senonian age, ranging upwards probably into the Lower Danian, the Nerinea and Niniyur beds belong to the rest of the Danian.

The absence in the Pondicherry and Vriddhachalam areas of any stage older than the Ariyalur is of especial interest in that it demonstrates incontrovertibly the overlap of these beds. Even in the Trichinopoly area the Ariyalurs overlap on to the Utaturs at Olaipaddi (Olapaudy), and for some distance in fact on to the crystallines. Such overlap in the Upper Cretaceous is matched not only in Assam but in other parts of the globe and is of importance in the Pacific region.

Including the few vertebrata we have a grand total of about 800 species of animals from the Cretaceous deposits of southern India. A large number of forms are common to two stages, and the following few species are found in the three lower: *Nautilus huxleyanus*, *Ampullina bulbiformis*, *Gyrodes pansus*, *Solariella radiatula*, and the rare *Lucina* (*Myrtea*) *arcotina*; some of the latter, however, are especially characteristic of one horizon, as in the cases of *Nautilus huxleyanus* (Trichinopoly stage and upper part of the Utaturs) and *Solariella radiatula* (Ariyalur).

Besides the saurian mentioned previously, the Vertebrata are represented by 17 species of fishes, but the remains are of the most fragmentary description, consisting in most cases of single teeth, and it is not certain from which group some of the specimens were originally derived. The majority of the fishes are elasmobranchs, belonging to the genera *Corax* (? *Carcharias*), *Lamna* (including *Oxyrhina*), *Odontaspis* and *Otodus*, all of them occurring in the Cretaceous of Europe; *Corax pristodontus* is a species common to the two regions, and the ray, *Ptychodus latissimus*, from southern India, is a widely distributed form. One fragment has been provisionally identified with the European ganoid genus, *Pycnodus*, while another member of the same order is referred to *Sphaerodus* under the name of *rugulosus* Eg. The only known teleostean fish from the southern Indian Cretaceous belongs to the European Cretaceous genus, *Enchodus*, and has received the name of *E. serratus* Eg.

As a result of Stoliczka's fossil determinations, it was concluded that a little more than 16 per cent. of the southern Indian Cretaceous invertebrates consist of forms known to occur in Cretaceous beds in Europe. This figure may require some correction in the light of further investigations, but no revision of the Indian faunas can refute the clear relationship between the two regions. With Assam the connection is an extremely close one, and it is obvious that the Cretaceous sea of the Coromandel coast stretched northeastwards and deposited sediments containing numerous identical fossils upon the margin of crystalline gneisses forming what is now the Shillong Plateau. There are distinct affinities with the Upper Cretaceous faunas of the Pacific Ocean, including those of Borneo, Japan, Queen Charlotte Islands, Vancouver, California and Chile; on the other side there is a close relationship with Madagascar and Natal. All the Cretaceous rocks of southern India appear to have been formed in shallow water, in the neighbourhood of a coast, and the relative elevation of the country has undergone but little change since. Then, as now, there was higher ground to the west, and the ancient coast-line seems to have been approximately parallel to the present, though a little farther to the west.

TANJORE

On the south side of the Cauvery, some eight or nine miles west of Tanjore and near the railway line, there crops out a friable, ochreous, fine-grained argillaceous sandstone, representing probably an originally calcareous rock from which the calcareous matter has been leached. Underlying the Cuddalore sandstones of the Vallam ridge, it rests directly upon the schists and gneisses which are seen to crop out at Budalur (Buttalur). The beds have yielded widely scattered casts of bivalves, and also a rather large free-growing bryozoan belonging to the genus *Cellepora*. Of the bivalves the only recognisable examples are specimens of *Inoceramus* belonging to one of the forms with strongly projecting and widely spaced concentric ribs, such as that which was at first assigned to *I. cripsianus* Mant. but which is probably closer to *I. balticus* Böhm. (one of the commonest Ariyalur fossils), *I. latus* Mant., or *I. brongniarti* Sow. Although the exposure occurs on the line of strike of the Ariyalur stage of Trichinopoly, and in all probability belongs thereto, it appears to be of the nature of an outlier and not continuous beneath the Cauvery alluvium with the beds north of the river. Its Ariyalur age is confirmed by the presence of the bryozoan, for bryozoa are amongst the commonest and most characteristic fossils of that stage.[1]

ARIYALUR STAGE IN MADRAS.

Amongst the descriptions by Dr. Stoliczka of the Cretaceous fossils from southern India, the following species of lamellibranchs are recorded from Sripermatur, twenty-five miles W.S.W. of Madras city and already mentioned as the type locality for a group of the Upper Gondwana containing marine fossils of Lower Cretaceous age :

Sphaeriola sp.,
* *Hippagus aemilianus* Stol.,
* ? *Yoldia obtusata* Stol.,
**Trigonoarca galdrina* d'Orb.,
Pteria (Oxytoma) fallaciosa (Stol.),
Pseudomonotis inops Stol.,
Limnaea oldhamiana Stol.,
Pecten arcotensis Stol.

Assuming the *Yoldia* to be correctly determined, three (asterisked) of the seven specifically identified forms are also found in the Ariyalur stage of the Trichinopoly district and Pondicherry settlement, *Trigonoarca galdrina*, as we have seen, being a type species and belonging to a characteristic Cretaceous genus. These eight specimens, unfortunately, were collected before the country was systematically examined, and there is some doubt as to the precise beds from which they were obtained. Some were from Sripermatur itself, others from Rajah's *Choultry*. The only Cretaceous fossils found by Foote, who mapped the Sripermatur country later, occurred in water-worn blocks of grey or greenish-grey, gritty sandstone, resting loosely on the surface of what he described as "Jurassic beds" near Sripermatur[2] —presumably the Neocomian (Barremian) deposits referred to in a previous chapter. The origin of these boulders was not traced and the fossils have since been mislaid ; amongst them were four or five species of ammonites, some belemnites, *Pleurotomaria*, and others.

THE "INFRA-TRAPPEAN" BEDS OF DUDKUR, GODAVARI DISTRICT.

In this chapter may be described some beds with a marine fauna, lying beneath the trap near the village of Dudkur (Dudukur), twelve miles west of Rajahmundry in the Godavari district. The traps of Rajahmundry are remote from other exposures of the Deccan volcanic suite but are associated with sediments carrying some of the typical fresh-water fossils of the Inter-Trappeans ; there is no doubt, therefore, as to their age. The lavas are found on both banks of the Godavari river but, on the right bank, between the basal basalt flows and the underlying

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[1] E. Vredenburg. *Rec.* XL, 336-339 (1910).
[2] *Mem.* X, 61 (1873).

Tripati sandstones which form what have been regarded in the past as the highest members of the Ellore Upper Gondwana outcrop and contain coniferous wood and marine lamellibranchs there intervene about 50 feet of white, yellowish or greenish sandstone, calcareous towards the top, with an upper crust from six inches to two feet thick of sandy limestone abounding in marine fossils. For a distance of a little under four miles, these beds are exposed along the base of the western half of the Pungadi hill range, in the vicinity of Dudkur.[1] The most abundant fossil is a *Turritella* which is said to be identical with or very closely allied to *T. dispassa* Stol. of the Ariyalur stage. Accompanying the *Turritella* are a *Nautilus*, a *Lunulites*, the chelae of a crab, about fifteen gastropods and eleven lamellibranchs. One species, *Cardita variabilis* Hisl., has been recognised as occurring also in a higher-lying inter-Trappean bed. Another and much more important identification is that of *Cardita* (*Venericardia*) *beaumonti* d'Arch. recently made by H. C. Das Gupta ;[2] the synonymy of *Cardita beaumonti* d'Arch., *C. visquesneli* d'Arch. & H., *C. obliqua* d'Arch., *C. subcomplanata* d'Arch. & H., *C. subcomplanata* Noetl. and *C. jacquinoti* Stol.—the last from the Niniyur stage of southern India—is accepted by Das Gupta. Amongst the genera identified are : *Rostellaria*, several forms of Muricidae, a *Volutilithes* close to the Tertiary *V. torulosa*, *Natica*, *Turritella*, *Dentalium*, *Meretrix* or allied genera (three species), *Cardita* (four species claimed), *Corbis* (? *Lucina*), *Glycimeris*, *Cucullaea* and *Ostraea*. The bulk of the fossils have not yet been specifically determined but, with the exception of *Cardita beaumonti* and the *Turritella*, none has so far been recognised as identical with any form in either the Cretaceous or Eocene beds of southern India. The facies of the fauna as a whole was originally described as Tertiary in spite of a notable absence of characteristic Tertiary genera ; the chief distinction from the Ariyalur fauna, according to Mr. W. T. Blanford (who included the Niniyur with the Ariyalur), is simply the want of any marked Cretaceous form[3] but the balance of evidence was thought by this authority to be in favour of referring the beds to the Cretaceous rather than to the Tertiary. The Dudkur fauna is described as having no resemblance to that of the Bagh beds of the Narbada valley which, in any case, are older. The Dudkur strata are similar in mineral character to the Lameta, and the discovery of *Cardita beaumonti* amongst their fossils places them as Danian.

The prevalent dip is about 10°, in a direction S.E. or E.S.E. There is said to be no sign of alteration by the superincumbent trap, but the variation in thickness of the thin limestone cap may be due to slight erosion prior to the lava flow ; there is, in fact, an appearance of slight unconformity where the volcanic rock rests upon the sedimentary, the surface of the latter being somewhat uneven as if denuded while the uppermost zone with its fossils is occasionally wanting. On the left bank of the Godavari, near Rajahmundry town, the infra-Trappean band has not been observed.

Significantly enough, it is in this area that an estuarine type of Inter-Trappean bed is found ; this will be dealt with in chapter XXVII, where also the Lameta and other infra-Trappean formations, some of which may be of Cretaceous age, are more conveniently described.

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[1] W. King. *Mem.* XVI, 234-238 (1880).

[2] *Quart. Journ. Geol. Min. and Met. Soc. Ind.*, Vol. V, 61 (1933).

[3] H. B. Medlicott & W. T. Blanford, *Man.*, 1st. Edit., Pt. I, p. 316 (1879).

ASSAM.

The Upper Cretaceous rocks of the Khasi Hills in Assam have so many species in common with the Ariyalur stage of the East Coast that the two regions must be regarded as having undoubtedly formed part of the same marine area. Cretaceous exposures are not confined to the Khasi Hills but are found as an irregular and interrupted fringe along the whole of the southern edge of the Shillong plateau. On the margin of the plateau itself these beds lie nearly horizontal, but over the escarpment they are bent down in a steep monoclinal flexure. The marked manner in which they thin out to the northward is well illustrated along the section south of the hill station of Shillong, where from a thickness of about 1,200 feet at the edge of the scarp the beds decrease in a distance of ten miles to about 100 feet. North of the main belt of outcrop are numerous small outliers lying in hollows of either the Shillong quartzites or the gneiss and granite, marking the position of Senonian or older valleys. In the southwestern part of the Khasi and Jaintia Hills, exposed in the Umngi (Mukai river), the base of the Cretaceous sequence is made up of the Sylhet Trap (see p. 1273) on which, over a considerable area, the marine sediments lie.

The key to a right comprehension of the Shillong Cretaceous succession lies in a true appreciation of the effect of deposition off a shore-line sinking and receding to the north as a result of the encroachment of a southerly sea, which crept northward, laying down a deep but thinning carpet of sediments ranging in age from Upper Senonian interruptedly to Tertiary.[1] As remarked by Captain R. W. Palmer,[2] were the Indian Ocean of today to rise to the extent of 5,000-6,000 feet and cover the margin of the Shillong plateau with littoral deposits, we should have a repetition of what happened during Upper Cretaceous and early Tertiary times.

The maximum dip in the monocline is about 60° near the eastern end of the exposure, but decreases westwards to about 25° at Nalikata where the folding is much less abrupt and its strike W.N.W.-E.S.E. instead of W.-E. Apart from the contour of the gorges, this change in dip and direction of the monocline is expressed in the topography, for the land surface is almost invariably a dip slope. In the Garo Hills the monocline becomes an overfold and thrust-fault.[3]

As a result of the northward encroachment of the sea the bottom beds of the Cretaceous are not continuous throughout in any meridional section, and the northern sequence is younger than its apparent equivalent in the south. Within the Cretaceous period, furthermore, there was a pause in the submergence of the Crystalline land, according to Captain Palmer, and a steep shore-line was cut ; this was followed by a later incursion of the sea burying the old line of cliffs. Evidence of this line of cliff is found along the parallel 25° 22′ N., where the sedimentary series rests upon a much more irregular floor than it does either to the north or south ; along this parallel Cretaceous beds may be sought for as often in the valleys as on the hill-tops, and show a corresponding marked and sudden increase in thickness. Banked against the old shore-line, they fill the old valleys which cut through the hills and, undisturbed and practically horizontal though they are, have boundaries which often traverse the contours in a striking manner. Examples of such ancient valleys are to be seen one mile W.S.W. of Rangmaw, one mile northwest of Phudjaud, and at Nongmawmairang. Palmer found that, south of these old valley deposits, the Cretaceous rocks appear suddenly and thickly developed along the old shore-line, which can be traced, running east and west, south of Rangthong and north of Phlangmawphra, and probably continuing westwards through the obscure country of Langrin. On the north side of the old cliff line the sedimentary beds occur exclusively on characteristically flat hill-tops as scattered outliers of deposits the bulk of which has been removed by denudation. South of the same line the Cretaceous silts rest on an old sea-bed which is at first comparatively flat and undisturbed ; further south, however, both the silts and the floor on which they repose bend over abruptly in the monocline already mentioned.

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[1] Gen. Rep., *Rec.* LVIII, 39 (1925).
[2] *Rec.* LV, 167 (1923).
[3] Gen. Rep., *Rec.* 72, 92 (1937).

In the plateau area to the north, Medlicott found it possible, in the Cherrapunji neighbourhood, to subdivide the beds into four stages, but the uppermost of these, the Cherra Sandstone, is now regarded as the basal stage of the Eocene ; the other three stages are :

3. Langpar Sandstone ;
2. Mahadeo Beds ;
1. Bottom Conglomerate.

In most of the sub-montane southern sections, it has been found possible to recognise only two subdivisions. The lower of these is typically unfossiliferous, arenaceous and littoral, comprising fine-grained ferruginous sandstones, passing down through coarser thick-bedded varieties and argillaceous, often carbonaceous, beds, to coarse arkose grits and conglomerates ; in the upper of the two groups fossils occur plentifully, argillaceous beds are common, and coal and limestone are occasionally developed. The lower portion of the massive sandstone appears to represent the Bottom Conglomerate of other sections, the upper portion, which is soft, ochreous, earthy and highly fossiliferous, corresponding to the Mahadeo stage. The mudstone, calcareous shale and impure earthy limestone of the younger group are evidently equivalent to the Langpar band, which is more consistent and widespread than the other stages.[1] The Mahadeo stage is said to have a very limited N.-S. range and to be not everywhere identifiable.

The so-called Bottom Conglomerate of the plateau, from 20 to 100 feet thick, in all probability does not represent a single geological horizon but traverses and coalesces with higher beds in the north. Its coarse and generally subangular débris, in the Cherrapunji neighbourhood, is almost entirely derived from the adjacent quartzites of the Shillong series.

The most general lithological character of the Mahadeo sandstones is the presence therein of glauconite. The beds also contain disseminated carbonate of lime and thick beds of earthy matter which exfoliate spheroidally on weathering. The Mahadeo beds constitute the most fossiliferous band.

The characteristic rock of the Langpar stage is a fine, pale sandstone with numerous scattered fragments of plants. With it are intercalated in a very capricious way discontinuous layers, thick or thin, of calcareous sandstone and every degree of sandy limestone ; in the coarser varieties of the former bryozoa are found, while in the purer limestones weathered sections of shells—mostly of small turreted gastropods—are common.[2] At the head of the Nongpriong valley this band is some 500 feet thick but northwards it rapidly thins out and apparently disappears entirely beyond Lairangao (Laitryngew).

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[1] A. M. N. Ghosh. *Rec.* LXXV, Prof. Pap. 4, pp. 3-4 (1940).

[2] H. B. Medlicott. *Mem.* VII, 178 (1869).

The most persistent member of the local succession is known as the Cherra Sandstone, conformably underlying the Nummulitic limestones. According to Dr. Fox, it forms the local base of the Eocene, and is unconformably related to the underlying Upper Cretaceous.[1] All the peculiar rocks of the southern scarp thin out and disappear northwards.

In the Maobclarkar (Mawbelurkar) coal basin, the basal conglomerate and the Cherra sandstone are in contact, but at the southern scarp of the plateau they are mutually separated by the glauconitic Mahadeo beds overlain by the fine sandstones of the Langpar stage ; these two intermediate stages, here about 400 feet in thickness, thin out to the northward against an original limit of deposition. At the same time, the matrix of the basal conglomerate, at the different levels, partakes of the nature of the superjacent horizon, and on all sections there is more or less a transition by interstratification, between it and the particular bed which happens to overlie it.

In the extreme south the Cretaceous is more shaly, the topmost beds in places consisting of a light blue clay at least 100 feet thick. Of the two subdivisions recognisable here and mentioned above, Bose gives the maximum thickness of the lower as not less than 700 feet and that of the upper as about 400 feet.[2] Fossils are generally scarce in the lower subdivision except in the eastern portion of the scarp where echinoids and bivalves occur in some profusion, and a sprinkling of gastropods and cephalopods have been collected in one or two localities.[3] Where the beds bend over and are exposed with a high dip in the low ground south of Tharia, the basal conglomerate is represented by a coarse, felspathic, ochreous sandstone, while the overlying beds, having a thickness of about 1,200 feet, consist of pale grey shales, locally nodular, calcareous or ferruginous, with some thin layers of earthy limestone or sandstone. The whole succession, besides being thicker than that exposed on the plateau north of the monoclinal axis, is earthy in character instead of sandy, a contrast implying a greater distance from the margin of the sea.

No fossils have as yet been found west of the Khasi Hills. In the Garo Hills the Cretaceous attains a considerable development as an arenaceous series, containing in places coal seams of some importance. The horizontal sandstones of the plateau here rest on a more deeply eroded and irregular gneissic surface than those of the Khasi Hills to the east. At the western end of the range the sandstones lap round the extremity of the Tura gneissic ridge, and the original relations of the rocks are nowhere better seen than they are here. The spur on which the station of Tura stands—some 2,000 feet below the crest of the ridge—has a W.N.W.-E.S.E. midrib of gneiss, which formed an ancient island ridge standing out of the Cretaceous sea covering that part of the Shillong plateau lying to the east.[4] Against the steep face of this ridge lean the scarcely disturbed Cretaceous sediments, made up of coarse grits and sandstones with a basal layer of white kaolin-bearing clay ; through these sediments the streams have excavated fresh channels. At the village of Aruak, a few miles west of Siju, a considerable thickness of Cretaceous rocks is found resting nearly vertically against the gneiss. Farther west, at the head waters of the Nitai and Bogai rivers, Cretaceous rocks are to be seen lying horizontally on a platform of gneiss, four or five miles broad and extending for about fourteen miles along the base of the main range.[1]

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[1] Gen. Rep., *Rec.* 73, 78 (1938).
[2] Gen.. Rep., 22-23 (1900-01).
[3] Gen. Rep., 27 (1901-02).
[4] E. S. Pinfold. *Rec.* L., 126 (1919).

Eastwards the Cretaceous of this area passes conformably beneath the Tertiaries near the Kapili (Kopili) river. Beyond this we have only isolated observations. The thin-bedded sandstones at the falls of the Kapili are believed to be of Cretaceous age, and typical Cretaceous coal is associated with sandstone and some hard sandy limestone resting flatly on the gneiss in the Nambar and Doigrung valleys, near Golaghat.

It is in the small local depressions of the old land surface on the plateau that the Cretaceous coal is found. There are many of these small coal basins and, while the most important of them are of early Tertiary age, some of those in the Garo Hills and Jaintia Hills are believed to be Cretaceous ; the best known of the latter category is perhaps the coalfield of the Umblai (Kynshiang) river in the Khasi Hills. In the opinion of Dr. Fox, the Cretaceous coal measures, the seams of which are apt to thin out rapidly, pass laterally into the marine beds and are probably lagoonal in origin.[2] The mineral itself has a persistent character and is remarkable as being less of a true coal and nearer a lignite than that found in the overlying Nummulitic group ; it has a smooth conchoidal fracture and gives out a dull wooden sound when struck. It has the additional peculiarity of containing numerous specks and small nests of fossil resin. Some of the coal is of good quality, but seams are thin and interbedded with slaty shales and sandstones.[3]

The majority of the fossils, examined by Dr. E. Spengler, come from the following five localities : Tharia Ghat ; below Mamluh (Maomluh) ; Laisophlang ; Sokha ; and Jowai ; the first three lying to the south of Shillong, the other two farther east. The fossils from below Mamluh, Laisophlang, Sokha and Jowai, are derived from the glauconitic Mahadeo stage. Medlicott was of opinion that the Tharia Ghat horizon lies somewhat lower, and nearer the base of the succession, but Dr. Spengler finds that the faunas are not sufficiently distinct to merit differentiation, and the following list includes specimens from all the above and half-a-dozen other localities, and indicates other parts of the world where many of the fossils or their allies are found : [4]

(N.)=Neocomian. (C.)=Cenomanian. (T.)=Turonian. (L.S.)=Lower Senonian. (U.S.)=Upper Senonian.

	South India.	*Baluchistan, Persia, Syria.*	*S. Africa and Madagascar.*	*Central and north Europe.*	*South Europe and north Africa.*	*America.*
Echinodermata—						
Cidaris sp.	(U.S.) ?					

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[1] T. H. D. La Touche. *Rec.* XX, 41 (1887).

[2] *Mem.* LVII, 46, 202 (1931).

[3] Gen. Rep., *Rec.* LVIII, 24 (1925).

[4] The half-a-dozen other localities have each furnished only one specimen. *Pal. Ind.* New Ser. Vol. VIII, Mem. 1, 61-64 (1923).

—	*South India.*	*Baluchistan, Persia, Syria.*	*S. Africa and Madagascar.*	*Central and north Europe.*	*South Europe and north Africa.*	*America.*
Discoidea sp.				(C.)[1](U.S.)[2]		
Echinoconus cf. *douvillei* Cott. & Gauth.		(U.S.)				
,, cf. *hemisphaericus* Breyn.				(U.S.)		
Stigmatopygus elatus (Forb.) (2a)	(U.S.)					
Hemiaster sp.	(U.S.)?					
Brachiopoda—						
Rhynchonella depressa Sow., var. *A.* Dav. (equivalent, according to Geinitz, to *R. compressa* (Lam.)).				(C.)		
,, *assamensis* Spengl.						
,, cf. *ariyalurensis* Stol.						
Terebratula biplicata Sow.	(U.S.)			(C.)	(U.S.)[3]	
Magellania [*Waldheimia*] sp.						
Lamellibranchiata—						
Inoceramus tuberculatus Woods				(L.S.)		
Lima (*Ctenoides*) *tecta* Goldf.	(U.S.)			(C.)(U.S.)		
,, (*Plagiostoma*) *ovata* (Nils.)		(U.S.)		(T.)		
,, cf. *coahuilensis* Böse						(U.S.)
Pecten [*Neithea* : *Vola* ; *Janira*] *faujasi* Pict.' Camp.		(U.S.)		(U.S.)	(U.S.)	
,, *assamensis* Spengl.						

Pecten. aff. *sub-decemcostatus* Vog.				(L.S.)(T.)[4]		
,, cf. *nilsoni* Goldf.				(T.)(U.S.)	(U.S.)	
,, (*Chlamys*) cf. *dujardini* Roem.		(U.S.)		(C.)(U.S.)		
Spondylus cf. *sulcatellus* Stol.	(U.S.)					
Plicatula sp.						
Anomia sp.						
Alectryonia arcotensis Stol.	(U.S.)			(T.)(U.S.)[5]	(U.S.)[5]	
,, *ungulata* Schloth.	(U.S.)	(U.S.)	(U.S.)	(U.S.)	(U.S.)	(U.S.)
Cardium (*Protocardia*) *delicatulum* Stol.	(U.S.)					
Exogyra sp.						
Gastropoda—						
Helcion corrugatum (Forb.)	(U.S.)					
Trochus aff. *striatulus* d'Orb.				(N.)?		
Gibbula aff. *jerdoniana* Stol.	(U.S.)					
?*Solariella radiatula* (Forb.)	(C.)(U.S.)		(U.S.)	(L.S.)(U.S.)		
Nerita (*Otostoma*) *divaricata* d'Orb.	(U.S.)	(U.S.)			(U.S.)	
,, cf. *d'Archiaci* Noetl.		(U.S.)				
Lunatia larteti Boehm.		(T.)				

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(1) *Discoidea subuculus* Klein (England).

(2) *Discoidea dixoni* Forb. (England).

(2a) H. C. Das-Gupta determines this as *Cyrtoma herschelliana* McClell. *J.A.S.B.*, New Series, XVI, 298 (1921).

(3) *T.* aff. *biplicata-semiglobosa* (S. Hungary).

(4) *Pecten decemcostatus* Münst. (Saxony).

(5) *Ostraea semipalna* Sow,

—	*South India.*	*Baluchistan, Persia, Syria.*	*S. Africa and Madagascar.*	*Central and north Europe.*	*South Europe and north Africa.*	*America.*
Natica sp.						
Pterodonta striata Spengl.						
,, (*Tylostoma*) cf. *pironai* Boehm. . . .					(C.) ?	
Turritella sexlineata Roem.		(U.S.)		(L.S.)	(U.S.) ?	(U.S.)
,, (*Torcula*) *pondicherriensis* Forb. . . .	(U.S.)					
Cerithium binodosum Roem., var. *indica* Spengl. . .				(L.S.)		
,, *intermixtum* Gein.				(C.)		
,, *vagans* Stol.	(U.S.)					
,, *imbricatum* Goldf.				(U.S.)		
,, cf. *pseudoclathratum* d'Orb. . . .				(U.S.)		
,, (*Campanile*) *turritelloides* Spengl. . .	(U.S.)[6]	(U.S.)[7]			(U.S.)[8]	
,, (*Orthochetus*) *mapeulensis* Douv., var. *assamensis* Spengl.		(U.S.)				
Aporrhais tegulata (Stol.)	(T.)-(U.S.)					
,, *rugosissima* Spengl.						
,, (*Helicaulax*) *haydeni* Spengl. . . .						
Calyptraphorus palliatus (Forb.) . . .	(U.S.)					(U.S.)
Eocypraea newboldi (Forb.)	(L.S.)-(U.S.)					

Transovula globulina (Stol.)						
Tritonium [*Nyctilochus*] *indicum* Spengl.						
Pseudoliva libyca Quass, var. *orientalis* Spengl.	(U.S.).[9]			(U.S.).[10]	(U.S.)	
? *Rapa* sp.						
Chrysodomus cancellata Spengl.						
,, aff. *granulata* (Stol.)	(L.S.)					
Fusus cf. *gracilis* Böhm.				(T.)(S.)		
? ,, *contortus* Spengl.						
Fasciolaria assamensis Spengl.						
Semifusus (*Lagena*) cf. *secans* (Stol.)	(U.S.)	(U.S.)[11]				(U.S.)[12]
Mitra [? *Turricula*] aff. *cancellata* Sow.					(T.)(L.S.)	
Lyria crassicostata Stol.	(U.S.)					
Mitreola (?) cf. *citharina* (Forb.)	(U.S.)					
Volutilithes renauxiana (d'Orb.)		(U.S.)		(T.)		
Voluticorbis muricata (Forb.)	(U.S.)	(U.S.)[13]	(U.S.)		(U.S.)	(U.S.)
Actaeonella [? *Trochactaeon*] sp.						
Actaeon cf. *ovum* d'Orb.					(T.)	
Cinulia (*Euptycha*) cf. *larvata* (Stol.)	(U.S.)					

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(6) *Cerithium inauguratum* Stol.
(7) *Campanile morgani* Douv. (Persia).
(8) *Campanile regens* Pethö (S. Hungary).
(9) *Pseudoliva subcostata* Stol. (Danian of Niniyur).
(10) *Pseudoliva ambigua* Bink (Maestricht.)
(11) Unnamed species in Zululand and Pondoland.
(12) "*Semifusus*" *dakotensis* Meek.
(13) *Volutilithes* cf. *crenulifer* Bay. (Persia).

——	South India.	Baluchistan, Persia, Syria.	S. Africa and Madagascar.	Central and north Europe.	South Europe and north Africa.	America.
Cinulia (*Avellana*) *sculptilis* Stol.	(U.S.)					
Bullina sp.						
Cylichna alternata d'Orb.	(T.)(L.S.)					
Cephalopoda—						
Nautilus baluchistanensis Spengl. . . .	(U.S.)	(U.S.)				
Tetragonites sp.						
Anisoceras sp.						
Heteroceras cf. ***hornbyense*** Whiteaves		(U.S.)				(U.S.)
Baculites vagina Forb.	(U.S.)		(U.S.)			(U.S.)
,, cf. ,, , var. *simplex* Kossm. . . .	(U.S.)					
,, cf. *anceps* Lam.				(U.S.)	(U.S.)	(U.S.)
? *Pachydiscus gollevillensis* (d'Orb.)	(U.S.)			(U.S.)		
,, *assamensis* Spengl.	(U.S.)[14]			(U.S.)[15]	(U.S.)[16]	

(14) *Pachydiscus egertonianus* (Forb.) : *P. neubergicus* Hauer.

(15) Kossmat. *Beitr. f. Pal.*, etc., Vol. XI, 134, (1898).

(16) Grossouvre. Recherches sur la craie supérievre. Stratigraphie générale, Table XXXIX, p. 830, (1901).

In addition to these Das-Gupta describes the following, most of them from the "Devil's Bridge":[1]

Goniopygus sp.

Echinocyamus kamrupensis Das-Gupta,

Pyrina ataxensis Cott. (abundant; found also in the Maestrichtian of Baluchistan).

Rhynchonella bosei Das-Gupta,

Magellania [*Waldheimia*] cf. *hebertiana* d'Orb.

Inoceramus simplex Stol. (found in the Ariyalur stage of S. India).

Pecten [*Vola*] *propinquus* Holz. (found in the Senonian of Europe).

,, ,, *aequicostatus* Lam. (found in the Cenomanian-Turonian of Europe).

Spondylus cf. *striatus* Sow.

Plicatula instabilis Stol. (found in the Ariyalur stage of S. India).

Septifer annectans (Stol.) (found in the Ariyalur stage of S. India).

Lunatia rotundata (Sow.) (found in the Ariyalur stage of S. India).

Protocypræa kayei (Forb.) (found in the Trichinopoly and Ariyalur stages of S. India).

Cerithium (*Campanile*) *inauguratum* Stol. (found in the Trichinopoly and Ariyalur stages of S. India; Das-Gupta calls it "*Cimolithium inauguratum*").

Cinulia (*Euptycha*) *spengleri* Das-Gupta,

Gryphaea vesicularis (Lam.) (a world-wide species, found in the Maestrichtian of Baluchistan as well as in the Ariyalur and Niniyur stages of S. India).

Near Tharia Ghat, A. M. N. Ghosh has collected gastropod casts of *Xenophora*, *Strigatella* and *Murex*, and an unusually large species of *Inoceramus*, two feet long and ten inches across[2].

Of the total assemblage, 13 species are new, while half the remainder are identical with species known from the Ariyalur beds of southern India and indicate an Upper Senonian age; in fact, of the 82 species which admit of exact determination, no less than 50 are characteristic of the Upper Senonian. Of the forms common to Assam and southern India, *Stigmatopygus elatus*, *Alectryonia ungulata*, *Nerita divaricata*, *Lyria crassicostata* and *Baculites vagina* are of particular importance; three of the new Assam species are also very closely related to Ariyalur species especially *Pachydiscus assamensis* which is a close ally of *P. egertonianus*. The Assam fauna shares 10 species with that of Baluchistan. The fact that typical Mediterranean elements such as *Hippurites*, *Actaeonella* and the Pulchellidae are missing altogether or rare in Assam leads to the conclusion that the Upper Senonian transgression of Assam started from the Indo-Pacific Ocean. The identity of so many of the Assam fossils with central European species is partly attributable to their cosmopolitan nature and partly to the fact that a much greater number of Cretaceous fossils happen to have been described from central Europe than from other parts of the world.

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[1] *Quart. Journ. Geol. Min. & Met. Soc. Ind.*, Vol. II, 25-34 (1929).

[2] Gen. Rep. *Rec.* LXXI, 27 (1936).

In the extreme east of the Shillong plateau, small exposures of sediments and trap in the southwestern portion of the Mikir Hills are classed as Cretaceous. Longloi Hill is a peak of gneiss lapped round on one side by a partially obscured sequence which includes 35 feet of a white argillaceous rock, massive below but stratified above, containing small quartz grains, surmounted by some 20 feet of beds comprising a light grey, plant-bearing clay-shale, dark carbonaceous shale and seams of coal with grains of fossil resin. The next highest exposure is one of Nummulitic Limestone[1].

Eight or ten miles to the northeast of Longloi, at the Jamuna Falls near Silbatta, the gneiss is overlain by a 20-foot band of decomposed hydrated trap mottled dark red and dull green, succeeded by the same thickness of a white, unfossiliferous, chalk-like but non-calcareous, argillaceous rock, nodular below but stratified above. The next highest exposure is again the Nummulitic Limestone.

The trap, usually decomposed but blue-green in colour when freshly broken, is exposed in several of the river beds of this area, resting directly on the gneiss. Its most northerly outcrop is recorded below the Nambor Falls, about a mile to the west of the Dhansiri river and some ten miles southwest of Golaghat; here it is a pale blue and ochreous mottled trap, immediately overlain by a series of grey clay-shales and shell limestones.

THE BAGH BEDS OF THE NARBADA VALLEY.

Marine Cretaceous deposits are thinly developed in the neighbourhood of Bagh, a town in the western portion of the Narbada valley, situated about 90 miles west and a little south of Indore, and 35 miles W. S. W. of Dhar, but not itself actually on Cretaceous rocks. The Bagh Beds, as they are called, stretch with long interruptions up the river valley from a point in Rajpipla State some 35 miles distant from the Gulf of Cambay, eastwards as far as Barwai (Barwaha), a town which is some 240 miles from the gulf coast. Here the Bagh sediments have been described by W. T. Blanford and by Vredenburg as marine equivalents of the fresh-water beds known as Lameta, and by P. N. Bose as unconformably overlain by members of this fresh-water group. The geographical distribution and inter-relationships of the Bagh and Lameta beds appears to support in some measure Bose's conclusion, but the possibility that the Bagh beds may correspond to lower horizons of the ill-defined Lameta series of other parts of India cannot yet be entirely ruled out. Whatever the true relationship or degree of equivalence between these two formations may be, the Lameta are best considered under the heading of Deccan Trap, with which they are here and elsewhere closely associated, and the extrusion of which commenced in all probability before the close of the Cretaceous period[2].

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[1] F. H. Smith. *Mem.* XXVIII, 78 (1898.)

[2] The exceptional occurrence of marine Cretaceous fossils recorded by Vredenburg in the basal conglomerate of what was thought to be the equivalent of the Nimar Sandstone near Barwai (Katkot Sandstone) is somewhat difficult to reconcile with the fresh-water aspect of the rest of the Nimar beds, unless the fossils were derived from an older deposit. The conglomerate was described as containing "typical Bagh (Cretaceous) fossils" and for this reason the Nimar Sandstone seems to have been looked upon as part and parcel of the Bagh series and both regarded as equivalent to the Lametas. The precise inter-relationship of the Nimar Sandstone, Bagh Beds and local Lametas is not quite clear, but in a general way the Nimar Sandstone appears to be older and the local Lametas younger than the marine Bagh beds, though all three are probably rightly included in the Cretaceous. The Nimar Sandstone has been included as a late member of the Gondwana system; whether any earlier member corresponding to the Mahadeva is also present in the Narbada valley, as Mr. Bose seems to have thought possible, is another matter to be cleared up in this area.

In the east, the Bagh beds overlie the Nimar Sandstone, which is almost entirely of fresh-water origin and has been described under the heading of Upper Gondwana, with no apparent discordance, but in Rajpipla further west it is admitted there may be a slight unconformity between the two[1]. In any case, the change in character from one formation to the other is marked, and the gap between the two may be more considerable than dip relationship might lead one to suppose. The total thickness of this interesting formation is, except in Rajpipla, usually insignificant, and its preservation is due to the protective covering of the Deccan basaltic flows. The Bagh beds occur chiefly along the edge of the traps, intervening between them and the metamorphic rocks below. Between Balwari and Barwai, where the expanse of the trap is less eroded, the Bagh beds accompanied by the gniess or the Bijawars, crop out as inliers in the lavas, but for fifty miles the stretch of the latter is unbroken along the Narbada valley except for a tiny outcrop of Inter-trappeans north of Mahesar[2].

The Bagh Beds in Central India can be subdivided into four zones, all of a calcareous nature :[3]

4. Coralline Limestone ;
3. Deola and Chirakhan Marl ;
2. Nodular Limestone ;
1. Oyster Bed.

None of these subdivisions attains any considerable thickness, and the total succession in Central India nowhere exceeds 80 feet. The beds reach their greatest thickness along the southern limit of the exposures and thin out to the north. The two upper do not extend so far west as the two lower groups.

The absence of the Oyster Bed in places does not necessarily signify a break in deposition more than that which would be caused by a change from fluviatile to shallow marine conditions. At Ghatia (Gatta), a short distance north of Barwai, the Oyster Bed, 1½ feet thick, is described as resting on an eroded surface of the Gondwana (Nimar) sandstone ; at Pipri-Amlipura, six miles northeast of Bagh on the other hand, there is no visible unconformity between the one foot Oyster Bed and the five feet of horizontal extremely coarse Nimar gritstones upon which it reposes. At Yalam, five miles west of Barwai, this subdivision is probably represented by a sandstone in which the same oysters are sparsely distributed at the base of the nodular limestone. It is met with in other places west of Bagh, always on top of the Nimar sandstones, but the oysters, though rather numerous at Chikli and Mongra, south of Kawant (Kawat), are never so abundant as they are at Ghatia or Amlipura. In Rajpipla this zone is seen here and there and takes the form of a brownish limestone, crowded with an *Ostraea* which appears to be of the same species as that found further east, and overlying in the usual way the Nimar Sandstone[1]. Upwards the Oyster Bed passes without a break into the Nodular Limestone, of which it is in reality a basal phase. The species of the Oyster Bed has been identified as *Ostraea leymeriei* d'Orb., a form found in the European Neocomian.

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[1] P. N. Bose, *Rec.* XXXVII, 172 (1908).

[2] W. T. Blanford. *Mem.* VI, 207-219 (1869) ; P. N. Bose. *Mem.* XXI, 23-44 (1884); E. Vredenburg. *Rec.* XXXVI, 109 (1907)).

[3] Vredenburg regarded the upper three subdivisions as a successive facies of a single Palaeontological stage but there is something to be said for P. N. Bose's view that these three groups are atenuated equivalents of the Utatur, Trichinopoly and Ariyalur stages of the Coromandel coast.

The subdivision tabulated above holds good in Central India. The Nodular Limestone is the most extensive of the three. It is a whitish, compact, argillaceous, generally nodular limestone, though at the eastern and westernmost outcrops in this region the peculiar nodular character is wanting. It shows some attenuation westwards but is nowhere entirely absent, and averages about 40 feet in thickness. Sometimes its base is not visible ; in the northern portion of the Man valley it rests directly on the metamorphics, but at Chirakhan and westwards throughout, the Nimar Sandstone intervenes. Fossils are plentiful in the Nodular Limestone near Barwai and west of the Man valley (see table below).

The Deola and Chirakhan Marl is a soft, almost flaggy band, never more than 10 feet thick, and is interesting chiefly as having yielded the majority of the fossils.

The Coralline Limestone is the rock of which the old Mohammedan fort and town of Mandogarh was built. It is yellow or red in colour, and consists chiefly of small fragments of bryozoa, shells, etc., which are conspicuous only on weathered surfaces ; the freshly broken surface has a somewhat granular, mottled appearance. It has a maximum thickness in the Man valley of about 30 feet, but thins out westwards ; it has been traced as far west as Umrali, near Ali, but is wanting in the district of Kawant.[2]

In Rajpipla the limestones correlated with the Bagh beds are very dissimilar lithologically and have nowhere yielded the fossils so characteristic of the latter, if we except the Ostraea bed with *O. leymeriei* or some very closely related form. In this State the thickness of the limestones is less than that of the underlying sandstones but is probably not much less than 1,000 feet ; both sandstones and limestones have been disturbed, in places considerably so. The unaltered beds are here black, occasionally greyish-white or greenish, generally fine-grained and compact, with coarse siliceous or shaly intercalations ; as a rule, however, they have been greatly affected by trap intrusions and altered to marbles.[3] The Rajpipla limestones have not been subdivided into the horizons recognised farther east.

Thin, lenticular, disconnected outcrops of the Bagh beds are described by Gupta and Mukerjee as occurring in the form of narrow fringes along the margin of the Deccan Trap in the Jhabua and Ali Rajpur States of the Central India Agency, and in the Vajiria, Agar, Naswadi, Borad and Chhota Udepur States of the Rewa Kantha Agency[4].

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[1] P. N. Bose. *Rec.* XXXVII, 171 (1908).

[2] P. N. Bose. *Mem.* XXI, 42 (1884).

[3] *Rec.* XXXVII, 171 (1908).

[4] *Rec.* 73, 195 (1938).

In Jhabua State and in the Ali Rajpur area to the south, the Bagh formation, which contains well preserved fossils, are characterised by extreme heterogeneity of composition and by variability in thickness of its component beds[1]. Scarcely more than 10 or 15 feet thick though attaining a maximum of 25 feet, and resting unconformably upon Aravalli rocks, they project as flat shelves from beneath the Deccan flows. Lateral variation makes it difficult to draw up an accurate section, but the following, according to B. C. Gupta, is the generalised sequence, which may perhaps include representatives of the Nimar Sandstone.

5. Cherty, porcellanitic bands, often much brecciated	3 feet.
4. Thick-bedded, siliceous limestone	10 ,,
3. Concretionary and gritty limestone	6 ,,
2. Calcareous grit	3 ,,
1. Calcareous conglomerate	4 ,,
	26 feet.

In the Gad Borad, the Nimar and Bagh beds, dipping very gently towards the S. S. E., are well developed and are said to comprise pinkish, coarse, gritty, quartzitic sandstone, overlain with no apparent unconformity by a thick bed of brownish, soft, calcareous shale containing innumerable lamellibranchs, most of them belonging to the genus *Ostraea*; the latter would ayyear to be or at any rate to include the Oyster bed at the base of the Bagh. Both sandstone and shale have been intruded by veins and sheets of Deccan trap[2].

The fauna from the Bagh Beds, though not copious, is interesting. The following list shows the horizons in which the fossils occur; the determinations, other than those of the echinoids which have been revised by M. Fourtau, and the cephalopods which have been re-examined by Mr. Vredenburg, require revision[3].

Some of these are described as "rough determination."

Fossils.	Nodular Limestone.	Deola Marl.	Coralline Limestone.	Relationships.
Anthozoa—				
Thamnastraea decipiens Dunc. . .		+		Cenomanian to Gosau of Europe.
Bryozoa—				
Ceriopora dispar Stol., . . .	+	+	+	Ariyalur stage of S. India.
Escharina sp., ...		+		
Onychocella [*Eschara*] sp. . .		+		
,, *Vincularia* sp. . .		+		

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[1] Gen. Rep. *Rec.* LXVIII, 71 (1934).

[2] Gen. Rep. *Rec.* LXIX, 81 (1935).

[3] *Mem.* XXI, 37, 40-41, 43 (1884); *Rec.* XXXVI, 109-125 (1907); *Ibid.* XLIX, 34-53(1918).

Fossils.	Nodular Limestone.	Deola Marl.	Coralline Limestone.	Relationships.
Vermes—				
Serpula plexus Sow.		+		
Echinodermata—				
Dorocidaris namadica (Dunc.) . .		+	+	Closely allied to *D. jullieni* Gauth. from the Aptian of Algeria.
Salenia keatingei Fourt. . . .		+		Resembles *S. mamillata* Cott. from the Aptian of France.
Cyphosoma namadicum Fourt. . .		+	+	Related to *C. peroni* Cott. from the Barremian of France and Switzerland.
Orthopsis indica Dunc. . . .		+		Related to *O. repellini* Desor, from the Barremian and Aptian of Europe.
Echinobrissus haydeni Fourt. . .		+		Related to *E. eddissensis* Gauth. from the Aptian and Albian of N. Africa.
Hemiaster fourteaui Chipl. . .	+	+	+	Fourtau's "*H. oldhami*", a name preoccupied for a Maestrichtian species from Baluchistan described by Noetling[1]. Related to *H. luynesi* Cott. from the Cenomanian of Palestine.
Opisaster subsimilis Fourt. . .	+	+	+	Related to *O. morgani* Cott. & Gauth. from the Senonian of Persia.
Brachiopoda—				
Rhynchonella depressa Sow. . .		+		Lower Greensand of Europe ; a variety occurs in the Cenomanian of Assam.
,, *plicatiloides* Stol. . .		+	+	Trichinopoly stage of S. India.
Lamellibranchiata—				
Ostraea leymeriei d'Orb. . . .	+			Neocomian of Europe.
Alectryonia arcotensis Stol. .		+		Ariyalur stage of S. India.
Pecten quinquecostatus Sow. .	+			Including the so-called "*P. quadricostatus*" and "*P. albus*". Found in the Gault to Lower Chalk of Europe and Africa, and in the Utatur, Trichinopoly and Ariyalur stages of S. India.
Lima (Acesta) obliquistriata Forb. .		+	+	Ariyalur stage of S. India.
Plicatula multicostata Forb. . .		+		Trichinopoly stage of S. India.
[*Lithophagus*] *Lithodomus archiaci* Leym.		+		Neocomian of Europe.
Inoceramus concentricus Park . .		+		Gault of Europe.

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[1] *See* G. W. Chiplonker. *Proc. Ind. Acad. Sci.*, Vol. VI, sect. B, July. 1937, p. 60.

Fossils.	Nodular Limestone.	Deola Marl.	Coralline Limestone.	Relationships.
Lamellibranchiata—(*contd.*)				
Inoceramus coquandianus d'Orb.		+		Gault of Europe.
„ *multiplicatus* Stol.		+		Trichinopoly stage of S. India.
Pinna laticostata Stol.		+		Utatur and Ariyalur stages of S. India; also the Neocomian of Europe.
Arca securis d'Orb.	+			
Cardium (*Protocardia*) *altum* Forb.	+	+		Utatur stage of S. India.
„ „ *hillanum* Sow.		+		Trichinopoly stage of S. India; also the Cenomanian, Turonian and Senonian of Europe.
Venus sp.	+	+		
Panope ("*Panopaea*") *arcuata* d'Orb.	+			Neocomian of Europe. Described as "*Panopaea* (*Myopsis*) "*arcuata*."
Gastropoda—				
[1] *Scaphella* (*Fulguraria*) *elongata* d'Orb.	+	+		Comparable to forms found in the Trichinopoly and Ariyalur stages of S. India; *Fulguraria elongata* is found in the Cenomanian and Turonian of Europe.
Lyria granulosa Stol.	+			Either the Trichinopoly or Ariyalur stage of S. India.
Fasciolaria rigida Stol.	+	+		Trichinopoly stage of S. India; also in the Cretaceous of S. Africa.
Tritonium [*Triton*] sp.	+	+		
Natica sp.	+	+		
Cerithium sp.	+	+		
Turritella sp.	+	+		
Cephalopoda—				
Placenticeras mintoi Vred.	+	+		Related to *P. tamulicum* Blanf. from the Trichiniopoly and Ariyalur stages of S. India.
Coelopoceras ("*Namadoceras*") *scindiae* Vred.	+			
Coelopoceras ("*Namadoceras*") *bosei* Vred.	+			

To these may be added some echinoids determined by Mr. G. W. Chiplonker[2].

Salenia mathuri Chipl. (related to *S. cylindrica* Arnaud, from the Aptian-Albian of France),

Diplopodia (*Tetragramma*) aff. *micropyga* Fourt. (species found in the Lower Cenomanian of Egypt),

Echinobrissus cf. *angutier* Gauth (related to a variety found in the Upper Cenomanian of Algeria),

Hemiaster holo-ambitus Chipl. (Fourtau's "*Opisaster* sp." from all three horizons of the Bagh Beds, described as related to *O. vignesi* Cott. from the Cretaceous of Palestine),

„ cf. *thomasi* Peron & Gauth. (species found in the Senonian of Algeria).

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[1] *Proc. Ind. Acad. Sci.*, Vol. VI, sect. B, 60-70 (July, 1937).

[2] *Rec.* XXXVI, 239 (1907).

According to M. Fourtau, the majority of the echinoids have incontestible affinities with early Cretaceous forms and the rest appear to be ancestors of middle Cretaceous species; by this authority the beds were, therefore, assigned to the Albian or Gault, an epoch which saw the first appearance of the genus *Hemiaster*. *Placenticeras mintoi* was thought by Vredenburg to resemble *P. uhligi* Choff. and *P. saadense* Per. & Thom. found in the Bellasian of Portugal and the Vraconnian of Algeria, each of these two sub-stages representing the upper portion of the Albian. According to Dr. Spath, however, the ammonite fauna of the Bagh Beds, limited as it is, is undoubtedly later even than the Cenomanian and is Turonian.[1] Several of the molluscs of the earlier collections were claimed to be identical with Ariyalur and Trichinopoly forms, though any similarity between the Bagh and southern Indian faunas was subsequently denied by Kossmat[2]. In making any such comparison, however, the extreme thinness of the Bagh deposits and the comparative paucity of their fauna have to be taken into account. Fossils recently procured from the Jhabua and Ali Rajpur areas show distinct relationships to the Trichinopoly and Ariyalur stages as well as to the Utatur, and their presence reduces the disparity which was thought by some to exist between the faunas of the Coromandel coast and the Narbada valley. According to a preliminary examination by P. N. Mukherjee, they include two lamellibranchs having close affinities with Utatur species from Pondicherry, *viz.*, *Astarte* (*Grotriana*) *jugosa* (Forb.) and *Circe* (*Gouldia*) *planissima* (Forb.); three Trichinopoly species, *Cardium* (*Protocardia*) *pondicherriense* d'Orb., *Circe* (*Gouldia*) *trigonioides* (Stol.) and *Cardium* (*Trachycardium*) *incomptum* Sow.; one form identical with a species found in both the Trichinopoly and Ariyalur stages, *viz.*, *Turritella* ("*Zaria*") *multistriata* Reuss and one comparable to the Ariyalur species *Meretrix* (*Callista*) *sculpturata* (Stol.)[3]. In addition there are two forms comparable to the Upper Cretaceous European species, *Ostraea curvirostris* Nilss. and *O. wegmaniana* d'Orb. These Bagh beds when traced northwards become less conglomeratic and are said to pass into typical Lameta beds, just as they are reported to do in the Dhar Forest area; this supposed passage requires confirmation.

It has been suggested that the Jhabua and Ali Rajpur fauna may be somewhat younger than that found further east, but the grounds for such a conclusion are not very strong. The tabulated assemblage given above was thought to belong to a single geological epoch, but whether further careful collecting will show that the sequence in the Bagh Beds, like that in the Giumal Sandstone of north-west India, is an extremely condensed one, including horizons ranging from the top of the Albian to the Upper Senonian, remains to be seen; the only certain conclusion which can be drawn at present is that the Bagh Beds comprise Turonian levels. If the presence of *Ostraea leymeriei* in the basal horizons has any important significance, the Bagh Beds cannot extend stratigraphically much below the basal Cenomanian. Looked at as a whole, the Bagh fauna shows relationships with the Cretaceous faunas of Europe, and a close affinity with a small fauna found on the southwest coast of Arabia.

Before leaving the Narbada area it is interesting to note that in the Dhar Forest area nearly the whole of the Nimanpur *pargana* is in the condition of a terrace intermediate in altitude between the deep Narbada valley to the south and the much loftier Malwa plateau to the north. This terrace is remarkably flat and preserves much the same level—some 900 feet above the sea—throughout its width from the foot of the Malwa scarp to the edge of the cliffs overlooking the Narbada. It is thought to represent an ancient Cretaceous peneplain of hard Bijawar and Vindhyan rocks, exposed by the denudation of the easily weathered overlying Lameta sediments. In that case it would have to be regarded as younger than the peneplain traced throughout the length of the Aravalli range by Heron and Middlemiss.

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[1] *Pal. Ind.*, New Ser., Vol. XV, Pt. V, 64 (1930).

[2] *Rec.* XXVIII, 42 (1895).

[3] Gen. Rep. *Rec.* LXVIII, 73 (1934).

CUTCH AND KATHIAWAR.

Cutch.—In Cutch the beds of the Umia series are covered unconformably by the Deccan Trap or by Tertiary rocks except in one place, where they underlie a thin bed of ferruginous oolitic rock which intervenes between them and the base of the traps forming Ukra (Ukhra) Hill, seven miles southeast of Lakhpat. The outcrop of this Cretaceous bed is ill seen, and nothing is definitely known as to the relationship between it and the subjacent formation but, although there is no marked contrast between them, the two faunas indicate an appreciable time gap. The Cretaceous beds occur only at the northern foot of the Ukra hills. It is thought that further examination will reveal the existence in this outlier of a far more complete fauna than that represented by the scanty remains so far available.[1]

The ammonites found in the beds indicate an Upper Aptian age and include :—

Colombiceras waageni Spath (Waagen's "*Ammonites* (*Deshayesites*) *deshayesi* (Leym.)"

Cheloniceras sp. juv. aff. *martini* (d'Orb.) (species found in the Upper Aptian of the Lower Alps),

Crioceras (*Tropaeum*) aff. *australis* (Moore) (species found in Australia).

A specimen of *Trigonia ventricosa* (Krauss) is also recorded.

Kathiawar.—On top of the Wadhwan Sandstone of Kathiawar, there are in places cherty beds or thin bands of limestone which recall the rocks of Bagh. In the neighbourhood of Wadhwan, there is a thin band of drab-coloured, tough, sometimes gritty or chalcedonic limestone containing marine fossils comprising chiefly bryozoa, a few small corals and a portion of an ammonite having a flattened keel, among a matted mass of broken indeterminable shells. The ammonite was described as resembling the Cretaceous "*Ammonites guadaloupae* Roem." ; if identical with the Bagh ammonite originally so named, it must now be called *Placenticeras mintoi* Vred. which is closely related to *P. tamulicum* Blanf., a form very characteristic of the Trichinopoly stage of southern India but said to occur also in the Ariyalur. Other localities in Kathiawar have yielded *Ostraea* and *Natica.* Although there have been found no fossils sufficiently well preserved to indicate the precise age of the beds, the general facies of those so far collected, as well as the lithological character of the rock in which they are preserved, suggests a correlation of the beds with the Cretaceous of Bagh, a relationship to some extent confirmed by the direct superposition of the beds on sandstones which have every appearance of being the equivalents of the Nimar sandstones of probably Upper Gondwana age. The relation of the Kathiawar succession to the overlying Deccan Trap is very similar to that of the Bagh sequence to the same igneous suite, there being a distinct erosion unconformity between the two.

RAJPUTANA.

As already indicated (page 1157), the Parihar Sandstone of northern Jaisalmer in Rajputana may range up into the Neocomian. Above this series comes another, named by Mr. R. D. Oldham the Abur beds, consisting of sandstones, shale and fossiliferous limestones, the last weathering to a dark red colour[1]. Among the limestones is a very characteristic thin fossiliferous band in which all the fossils except the oysters have been converted into a yellow substance and contrast conspicuously with the matrix in which they occur. This band is known locally as "Abur stone" and is employed for building purposes, especially in the construction of temple thresholds. Its fauna has not yet been worked out in detail but, according to Dr. Spath, includes a large number of specimens of an Aptian group of ammonites of considerable interest[2]. Some are almost identical with forms from Alberta, Canada; others are comparable to *Hoplites macconnelli* Whiteaves from the same beds, and to '*Hoplitides*' *laeviusculus* v. Koen. from the Lower Aptian of north Germany. Another ammonite, *Deshayesites* (?) *aburensis* Spath is an ancestral type, and might almost be included in the genus *Pseudohaploceras* Hyatt. The horizon indicated is Lower Aptian.

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[1] Spath. *Pal. Ind.* New Ser., Vol. IX, Mem. 2, 700, 758 (1933).

BALUCHISTAN AND WESTERN SIND.

Baluchistan.—From the Gumal river, which forms the northern boundary of Baluchistan, the Cretaceous has been traced as a broad crescentic outcrop, partly concealed beneath outlying area of Nummulitic rocks, and sweeping southwards and westwards to the Quetta-Pishin syntaxis; thence it has been followed southwards, again hidden in places by the Nummulitics, especially by a large tract of those rocks east of Kalat town, and interrupted by many anticlinal inliers of Jurassic, to within a few miles north of Karachi. In Sarawan, Jhalawan and Makran, and possibly in other parts, the middle portion of the Cretaceous sequence appear to be un-represented, and there is unconformity within the system as well as with the underlying Jurassics. The lowest Cretaceous beds exposed are the Belemnite Shales but, where these are absent, Lower Cretaceous limestones are seen encircling the great anticlinal bosses of Jurassics composed in some cases of Middle Jurassic limestones, in other of Liassic beds. In the Thal area between Loralai and the Marri hills, for example, the Belemnite beds form oval ring-like exposures round cores of massive limestones which were at first assigned to the Cretaceous but are now regarded as Jurassic. Throughout Baluchistan, the Barremian, Aptian, Albian, Cenomanian, Turonian and Lower Senonian are invariably missing.

The Belemnite Beds which in the country between Sharigh and Spintangi and in the Chappar rift were originally referred to as the Chappar Shales, are described as a series of dark grey or black shaly beds, often containing an admixture of volcanic ash, overlain by red and green mottled shales and thin-bedded limestones, capped in their turn by a characteristic white limestone containing *Orbitoides*; since this white limestone is of Upper Cretaceous age (Mæstrichtian; there must be a long time gap between them and the underlying Belemnite Beds. Including the 200 feet of this white limestone at the top, the thickness of the beds appears to be about 1,000 feet, but there are great variations owing partly to the manner in which the soft shaly beds have yielded to compression, and partly to the erosion of the upper beds previous to the deposition of the next succeeding group. Locally the shaly beds are abundantly fossiliferous but, with the exception of a few ammonite fragments, the only forms so far found are well preserved belemnites belonging chiefly to the *dilatata* group[3]. The following have been identified by Noetling and indicate a Neocomian age, including the lower or Valanginian stage thereof and possibly a portion of the Upper or Hauterivian stage[1].

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[1] *Rec.* XIX, 159 (1886).

[2] *Pal. Ind.*, New Ser., Vol. IX, Mem. 2, 800-801 (1933).

[3] R. D. Oldham. *Rec.* XXV, 19 (1892); Gen. Rep. *Rec.* XXXVIII, 29 (1909).

Belemnoidea—

Belemnites latus Blainv.? (found in France ; one damaged specimen only),
,, (*Hibolites*) *subfusiformis* Rasp. (a variable form but the commonest species found in France),
,, ,, ,, , var. *baluchistanensis*,
,, (*Hibolites*) *pistilliformis* Blainv. (found in France),
,, (*Duvalia*) *dilatatus* Blainv. (a variable form ; found in France).

Ammonoidea—

Hoplites amblygonus Neum.,
Holcostephanus sp. (group of *H.* (*Rogersites*) *astierianus* ; Dr. Spath adopts the spelling "*Olcostephanus*"
Perisphinctes (?) sp.,
Phylloceras cf. *velledae* d'Orb.,
Crioceras sp.,
Fragments of aptychi belonging to the *imbricati* and *punctati* groups.

Fossils from a limestone in that part of the Dunghan range lying within the Marri country include two foraminifera identified by Col. L. M. Davies as *Orbitoides media* d'Arch. and *Omphalocyclus macropora* Lam. They come from the lower 500 feet of the limestone, which has been loosely referred to as the "Dunghan Limestone", and indicate the presence of the Danian. The middle portion of the limestone is of Palæocene age, and the upper Lower Eocene[2].

In the range containing the Takatu peak to the north of Quetta, the massive Jurassic limestone has been thrust southeastwards over the Cretaceous. In the vicinity of Quetta, the Belemnite Beds appear to be represented by not less than 500 feet of characteristic unfossiliferous fine-grained shaly or flaggy limestones and calcareous shales, chiefly white or cream-coloured but variegated or alternating with patches or bands of purplish red colour. About twenty-five miles to the north of Quetta, similar beds are to be seen stratigraphically overlying a mass of conglomerate, probably 1,000 feet thick entirely composed of rolled pebbles of doleritic material. This conglomerate succeeds a dark limestone probably referable to the Jurassic, and may, therefore, represent a basal stage of the Cretaceous older than the Belemnite Beds[3]. In this locality beds of basalt are also associated with the shales, some of them at least intrusive. A similar sequence of conglomerate and variegated calcareous shales is reported west and north-west of Kandahar in Afghanistan.

In Sarawan, Jhalawan and Mekran, the Belemnite Beds, here black and splintery are succeeded by the Parh Limestones and these by the Lituola Beds[4]. All three stages were assigned by Vredenburg to the Lower Cretaceous, but ammonites from the Parh Limestones have since been found to indicate a Turonian age[1]. This being so, there must be a marked break between the Neocomian Belemnite Shales and the Parh beds. These three stages attain a great thickness in the neighbourhood of Khozdar and Zidi where they build up lofty ridges without the aid of any exposed Jurassics[2](H).

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[1] *Pal. Ind.* Ser. XVI, Vol. I, Pt. 2, p. 1 (1897) ; *Ibid.*, New Ser., Vol. XXV, Mem. 1, p. 135 (1939). *Gryphaea oldhami* Noetl. originally included in the list, did not come from the Belemnite Shales (Gen. Rep. 1898-99, 52).

[2] *Geol. Mag.*, LXXVIII, 316-317 (1941).

[3] W. T. Blanford. *Mem.* XX, 142 (1883).

[4] These two upper stages seem to have been included as part of the Belemnite Beds by early workers.

The Parh beds are regularly stratified, porcellanic limestones, usually of an intensely white colour except for some bright red beds mostly at the base of the stage.

The Lituola Beds consist of buff or pale green, flaggy limestones and shales containing numerous small foraminifera, principally of the genus *Lituola*; this stage would seem to correspond to the Lower Senonian (Emscherian).

Above the Lower Cretaceous of this area, therefore, there is an unconformity and similar though much smaller breaks are discernible between the Upper Cretaceous and the overlying Laki, between the latter and the Kirthar (both Eocene), and between the Kirthar and the Nari (Oligocene), indicating repeated irregular denudation and encroachment. In the Thal-Chotiali area, the unconformity above the Belemnite beds is unmarked by any difference in dip and there has been no noticeable disturbance in spite of a considerable lapse of time between the two epochs.[3]

The Upper Cretaceous in Baluchistan is a very variable formation, consisting sometimes mostly of limestones, sometimes mostly of sandstones, and sometimes of a combination of shales, sandstones and limestones; in the Pab range it is represented by thousands of feet of coarse sandstones[4]. Its thickness is equally inconstant, and in some places the whole group is absent.

In Sarawan, Jhalawan and Mekran, the Upper Cretaceous includes enormous intrusive masses of dolerite, basalt and serpentine, belonging to the Deccan Trap suite. Omitting these, the local classification is as follows, the various rock groups being scattered all over the region, especially in the synclinal areas between the great anticlinal ridges of Jurassic limestones, and the sequence showing considerable variation:

4. Volcanic conglomerates, accompanied by shales with *Cardita beaumonti*.	50-300 feet
3. Olive Shales, with *Cardita beaumonti*	200-400 ,,
2. Pab Sandstones	
1. Hemipneustes Beds	100-300 feet.

In another section, Vredenburg gives the following succession :—

3. Olive shales and sandstone, sometimes calcareous, with *Cardita beaumonti*	350-400 feet
2. Pab series of black-weathering sandstones and conglomerates .	700 ,,
1. Whitish limestones, partly arenaceous, with *Orbitoides* . . .	320 ,,

The Hemipneustes Beds are grey limestones and calcareous shales characterised by the Maestricht echinoid, *Hemipneustes*, and especially well developed in the Morau anticline to the north of Narmuk in Sarawan, and in Jhalawan near Kharzan and south of Karu.

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[1] *Vide* Col. L. M. Davies. *Proc. Sixth Pacif. Sci. Congr.*, 1939, p. 485.

[2] E.W. Vredenburg. *Rec.* XXXVIII, 200 (1909).

[3] R. D. Oldham. *Rec.* XXV, 20 (1892).

[4] *Rec.* XXXVIII, 196 (1909).

The Pab Sandstones attain an enormous thickness in the range of that name which consists largely of them. Massive, rather coarse, and accompanied by volcanic material, they appear to dovetail into the Olive Shales and *Cardita beaumonti* beds and to occur at more than one horizon therein. In many places *Cardita beaumonti* recurs at all levels of the thick Pab sandstones[1].

The Olive Shales, which are best seen south of Karu, contain numerous ammonites. Their colour is probably due to the presence of volcanic dust, while occasional interbedded volcanic ash beds are to be regarded as forerunners of the Deccan Trap outburst[2]. Interbedded at intervals with these shales are thin bands of a peculiar, dark, brittle, porcellanoid rock, often full of calcareous concretions similar to those found in the corresponding horizon in the Des valley.

The bands of sandstone and dark limestone containing the *Cardita beaumonti* fauna are quite thin—usually from 20 to 40 feet—but they are followed by sandstones and arenaceous shales or, near Karu, by a great thickness of massive brown limestones with fossils which do not weather out; over all come tuffs or lavas of the Deccan Trap, the former sometimes crowded with fossils none of which weathers out with the exception of a very large species of *Nautilus*. The volcanic conglomerates of the *Cardita beaumonti* Beds and the volcanic material of the other stages are all connected with the Deccan Trap disturbances.

In much of northern Baluchistan, the Upper Cretaceous, when not represented by the white *Orbitoides* bearing limestone, appears to be absent and the Belemnite Shales are succeeded by the Dunghan Limestone, a formation which was referred to the Upper Cretaceous in the last edition of this Manual but which,there is every reason to believe, consists for the most part of Palaeocene and Lower Eocene strata, though the topmost Cretaceous horizon of the *Cardita beaumonti* beds may have been included in some sections. In the hill-range east of the Quetta plain, Griesbach found abundant rudistids in some of the limestones, which are described as very similar to the "Hippuritic Limestone" of Persia; a few hundred feet of these rocks are seen near Sir-i-ab, the base not being exposed[3]. The Upper Cretaceous of the Des valley and Mazar Drik both in the Marri Hills, was divided by Noetling into many zones[4], which have been correlated by Vredenburg with the succession in southern Baluchistan detailed above[5], and have yielded the bulk of the numerous fossils obtained from the Upper Cretaceous of Baluchistan.

The Hemipneustes Beds, forming the base of the Upper Cretaceous in Jhalawan, from the three localities, Mula Pass, Wad and Karu, have yielded:

Foraminifera—

Omphalocyclus macropora (Lam.) (especially large and abundant towards the top of the stage found also in Europe, Tibet, E. Persia and Somaliland).

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[1] In his paper in the Records (XXXVIII, 199) Vredenburg places the Pab sandstones above the Olive shales, whereas, in his introductory note to *Pal. Ind.*, New. Ser., Vol. III, Pt. 1, p. vii, he reverses the order; sections drawn in the latter show the Olive shales overlying the Pab sandstones.

[2] E. Vredenburg. *Rec.* XXXVI, 181 (1907).

[3] *Mem.* XX, 140 (1883).

[4] *Centralbl. f. Min. Geol. u. Pal.*, 1903, p. 515; see also *Pal. Ind.*, Ser. XVI, Vol. I, Pt. 3. (1897); and Gen. Rep. 1898-99, 52.

[5] *Rec.* XXXVI, 172 (1907).

Echinoidea—

Hemipneustes compressus Noetl. (abundant),
Hemiaster tamulicus Kossm. (found in the Ariyalur stage of S. India).

Lamellibranchiata—

Gryphaea [*Pycnodonta*] *vesicularis* Lam. (abundant ; a world-wide form, found also in the Ariyalur stage of S. India),
Alectryonia larva (Lam.) (usually infrequent except in the uppermost zones),
Pecten [*Neithae*] *striatocostatus* Goldf.

Gastropoda—

Nerita (*Neritina*) *d'Archiaci* Noetl.,
,, (*Otostoma*) (Noetling's "*Neria pontica*" ; found in the Ariyalur).
,, *divaricata* d'Orb.
Pyrgulifera [*Hautkenia*] *striata* (Douv.).

Cephalopoda—

Peroniceras sp. (same species as in " Zone 4 " of the Des valley),
Pachydiscus dülmesis Schlüt.,
Baculites sp.

The Hemipneustes Beds of the south are thought to correspond principally to " Zones 7-18 " in the Des valley, and to " Zones 3-9 " at Mazar Drik ; among the fossils collected from these zones in the Des valley and at Mazar Drik occur the following : [1]

Foraminifera—

Orbitoides media d'Arch. (especially adundant at the boundary between the Campanian and Maestrichtian in Europe).
Orbitoides hollandi Vred.,
Lepidorbitoides socialis (Leym.) (with this Douvillé synonymises *Orbitoides minor* Schlumb found in the Sulaiman range, in the Niniyur stage of S. India and in its equivalent along the east coast of Madagascar),
Omphalocyclus macropora (Lam.) (in places large and plentiful).

Echinoidea—

Cyphosoma speciale Cott. & Gauth.,
Noetlingaster (*Noetlingia*) *paucituberculata* (Noetl.) (Noetling's " *Protechinus paucituberculata*[2].
Clypeolampas helios Noetl.,
Clypeolampas vishnu Noetl.,
Hemipneustes compressus Noetl. (abundant ; closely resembling *H. pyrenaicus* Heb. from the Upper Cretaceous of the Pyrenees),
Pyrina orientalis Cott. & Gauth. (Noetling's *P. ataxensis* Cott.),
Pyrinagigantea Noetl.,
Holectypus baluchistanensis Noetl.,
Cidaris sulaimani Noetl. (closely related to *C. persica* Cott. & Gauth.),
Echinanthus (?) *griesbachi* Noetl. (probably belongs to a new genus[3].

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[1] Many other forms are listed by Noetling, but Vredenburg implies that the determination are not all reliable. The following are apparently accepted by Vredenbung, but their exact horizon in the Upper Cretaceous is uncertain : *Modiola vishnu* Noetl., *Cardium harnaiense* Noetl., *Crassatellites* ("*Crassatella*") *macrodonta* (Sow.), *Arctica* ("*Cypriana*") *mazariana* (Noetl .), *Roudairia crassoplicata* Noetl., *Volutilithes septemcostata* (Forb.) (Noetling's " *Voluta latisepta* Stol. "), an Ariyalur form, *Ostraea acutirostris* Nilss., a form specially characteristic of the *Cardita beaumonti* beds of Europe, Egypt and Persia (the specimens from the Ariyalur stage so named are considered by Douvillé to be identical with his *O. orientalis* from the *Cardita beaumonti* beds of Baluchistan), and *Alectryonia ungulata* Schloth. (another Ariyalur species, found also in other parts of the world : Vredenburg identifies it as *A. larva* (Lam.) The following additional forms are included in the lists published in *Pal. Ind.*, Ser., XVI, Vol. I, Pt. 3 (1897) : *Cyclolites medlicotti* Noetl., *C. regularis* Leym., *Echinoconus gigas* Cott., *Exogyra pyrenaica* Leym., *Spondylus santoniensis* d'Orb., *Pholadomya indica* Noetl., *Corbula harpa* d'Arch. & H. *Radiolites subdilatata* Goin. *Cerithium* [*Pyrazus*] *vishnu* Noetl., *Voluta pseudocostata* Noetl., Noetling's *Trochus lartetianus* Leym. from Mazar Drik and the Des valley has been recognised in the Maestrichtian of Oman ; it is a European species. Bion identifies *Inoceramus balticus* Bohm from the Kaha Pass between Marri and Dragal (west of Dera Ghazi Khan), and also *Exogyra decussata* Coq., the former an Ariyalur species (*Rec.* LVI, 265-6 (1924)).

[2] *Rec.* XLI, 46 (1911.)

[3] *Rec.* XLIV, 14 (1914).

Echinoidea—*contd.*

Hemiaster tamulicus Kossm. (an Ariyalur species; identical with *H. blandfordi* Noetl.
Hemiaster oldhmai Noetl.

Lamellibranchiata—

Alectryonia pectinata (Lam.) (an Ariyalur species of world-wide distribution).

Alectryonia ungulata Schloth. (an Ariyalur form; identified by Vredenburg as *A. larre* (Lam.),
Gryphaea (*Pycnodonta*) *vesicularis* (Lam.) (an Ariyalur species of world-wide distribution,
Pecten (*Neithea*) *quinqueangularis* Noetl.,
,, ,, *faujasi* (Pict. & Camp.) (Noetling's "*Neithea quadricostata* Sow." appears to replace *P. striatocostatus* found in the south),
,, (*Chlamys*) *dujardini* Roem. (found in the Cenomanian to Upper Senonian of Europe, and possibly in the Upper Senonian of Assam),
Pholadomya tigris Noetl.,
Bournonia or *Biradiolites* sp. (Noetling's "*Radiolites muschketoffi*").

Gastropoda—

Turritella sexlieneata Roem. (found in Assam, and other parts of the world),
,, *quadricincta* Goldf.,
,, *forgemolli* Coq. (Noetling's "*Nerinea quettensis*"),
Certhium buddha Noetl.,
Nerinea ganesha Noetl. (erroneously emended by Vredenburg to "*Cerithium* (*Campanile*) *ganesha* (Noetl.)" recognised in the Maestrichtian of Oman)
Volutilithes renauxiana (d'Orb.) (Noetling's "*V. dubia*"; found in Assam).
Gisortia baluchistanensis Noetl.,
,, *benedicti* Vred. (a very large species[1]).
Nerita (*Neritina*) *d'Archiaci* Noetl.,
Pugnellus digitatus Noetl.,
,, *crassicostatus* Noetl. (found in the Lower Cretaceous of Madagascar; closely allied to *P. uncatus* (Forb.) in the Ariyalur stage of S. India).

Cephalopoda—

Sphenodiscus acutodorsatus Noetl. (abundant in places),
,, cf. *shiva* (Forb.) (very abundant; found in the Airyalur stage),
Pachydiscus dülmensis Schlüt.,
Heteroceras polyplocum Roem.,
Peroniceras sp.,
Gaudryceras cf. *kayei* (Forb.) (species found in the Ariyalurs, and in other parts of the world)
Baculites binodosus Noetl. (exact horizon uncertain, but probably the same as that of *Sphenodiscus acutodorsatus*).

The fossiliferous horizon of the Olive Shale stage of Jhalawan is characterised by what Vredenburg describes as *Cardita subcomplanata* d'Arch. & H.[2] and by numerous specimens of *Alectryonia larva* (Lam.); in addition there are found: *Pugnellus crassicostatus* Neotl., *Sphenodiscus ubaghsi* de Gross. closely related to *S. binkhorsti* Böhm. from Maestricht, characteristic of the last of the European ammonite zones[3] *Schlueteria tarteti* Seunes, *Pachydiscus neubergicus* v. Hauer, *Baculites* sp. and many other fossils[4]. In the Des valley it is represented by "Zones 19-23" and at Mazar Drik by "Zones 10-13"; from these come;

Echinoidea—

Trochosmilla protectans Noetl.,
Orthopnis perlata Noetl.,
Hemipneustes compressus Noetl. (rare),
Holectypus baluchistanensis Noetl.,

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[1] *Pal. Ind.*, New Ser., Vol. VII, Mem. 3, 51, (1927).

[2] According to Dr. L. R. Cox, Noetling's "*Cardita subcomplanata* d'Arch. & H." from the Upper Cretaceous of Baluchistan is smaller and different species (*Trans. Roy. Soc. Edin.*, LVII, 69, (1934); Vredenburg, on the other hand, approves apparently of the identification (*Rec.* XXXVI, 176, 177, 181, 183 (1907.)

[3] *Rec.* XXXVI, 192 (1907).

[4] *Rec.* XXXVI, 181-2 (1907).

Lamellibranchiata—

?*Cardita* (*Venericardia*) *subcomplanata* d'Arch. (see note (1) on previous page; species recognised also in the Maestrichtian of Oman),

Ostraea (*Flemingostraea*) *morgani* Vred.[1]

Plicatula hirsuta Coq. (Noetling's "*Hinnites*(?) *foliaceus*"; found also in the Maestrichtian of Oman),

Cardium loralaiense Noetl.,

Crassatellites [*Crassatella*] *austriaca* (Zitt.) Douv. (Noetling's "*Cyprina desensis*"; found also in the Maestrichtian of Persia and Oman and in the Gosau of Europe),

Chama callosa Noetl.,

Gastropoda—

Turritella sexlineata Roem.,

,, *quinquecostata* Noetl.,

,, *quadricincta* Goldf.,

Nerinea ganesha Noetl.,

Pugnellus crassicostatus Noetl.,

,, *digitatus* Noetl.,

,, *giganteus* Noetl.,

Gisortia cossmanni Vred.(Noetling's "*Ovula expansa* d'Arch. & H."; equivalent to *G. orbignyi* May,[2]

Volutilithes renauxiana (d'Orb.),

Physa [? *Bullinus*] *prinsepii* Sow.

Cephalopoda—

Sphenodiscus ubaghsi de Gross.,

Indoceras baluchistanense Noetl.,

Pachydiscus sp. (probably *P. neubergicus* v. Hauer).

Near Khatan was collected the crustacean, *Ranina griesbachi* Noetl. The occurrence in both the Des valley and Mazar Drik areas of *Physa prinsepii*[3] or *Bullinus prinsepii euryhalinus*, as Dr. Annandale prefers to call it[4] a form typical of the fresh-water inter-Trappean sediments, is of special interest; washed into the sea from some neighbouring estuary these shells, by their presence in beds containing a marine fauna of Maestrichtian age, confirm the conclusion that, whatever the final limit of the Deccan Trap period may be, the commencement dates at least as far back as the Maestrichtian or Lower Danian[5]. Vredenburg correlates the Hemipneustes Beds with the Valudayurs of southern India (Campanian), and the Olive Shales with the Trigonoarca Beds (Maestrichtian). A small Maestrichtian fauna from the Oman peninsula of Arabia has seven species in common with the Baluchistan assemblage.[6]

The youngest zone with identifiable fossils in the Baluchistan Cretaceous is a thin one comprising sandstones associated in some places with dark brown or black limestones, and characterised by the presence of the globose *Cardita* (*Venericardia*) *beaumonti* d'Arch. & H., to which *C.* (*V.*) *lybica* Zitt. from Egypt is so closely related as to be perhaps a mere variety; other intimately allied forms are *C.* (*V.*) *ameliae* from the Maestrichtian of Algeria, *C.* (*V.*) *visquesneli* d'Arch. & H., *C.* (*V.*) *obliqua* d'Arch., *C.* (*V.*) *subcomplanata* d'Arch. & H. and *C.* (*V.*) *jacquinoti* Stol. Other fossils recorded from the Cardita beaumonti beds of

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[1] *Rec.* XLVII, 197 (1916).

[2] Rec., LVIII, 360 (1925,)

[3] *Rec.* XXXVII, 19 (1908).

[4] *Rec.* LI, 53 (1920).

[5] *Rec.* XXXV, 117 (1907)

[6] See Martin Less *Q. J. G. S.*, Vol. LXXXIV, 585 (1928).

Baluchistan are *Cardium loralaiense* Neotl. and *Gisortia expansa* (d'Arch. & H.).[1] This stage falls into the Upper Danian (Montian) and corresponds to part at least of the Niniyur beds of southern India. In the latter are *Cardita* (*Venericardia*) *jacquinoti* d'Orb. which is very similar to and perhaps identical with *C.* (*V.*) *beaumonti*, and *Turritella elicita* Stol. which can also be closely matched in the Cardita beaumonti beds ; a large mollusc in the Niniyur , however, has its counterpart in *Nerinea ganesha* Noetl. found in the Hemipneustes Beds.

In the Des valley the Cardita beaumonti beds contain what has been described as a variety—*baluchistanensis*—of *Cardita beaumonti*, recorded also at Mazar Drik, and are followed by 100 feet of black unfossiliferous shales, and these are overlain by the Laki limestone of Ypresian age. In Jhalawan, 300 feet or more of Cretaceous strata with unidentifiable fossils, as well as tuffs and basaltic lava beds, intervene between the Cardita beaumonti stage and the Laki limestone, but there is here no passage up from the Cretaceous to the Palaeocene-Eocene as was at one time supposed.

Interstratified with volcanic material, consisting principally of tuffs and agglomerates, Cretaceous beds are present in north Chagai. Among them have been recognised the Cardita beaumonti beds, the Olive Shales, and the probable equivalents of the Hemipneustes Beds and Belemnite Shales. Some difficulty has been experienced in estimating the precise age of all the marine sediments, ranging from Cretaceous to Eocene, found interstratified with the Volcanic material in this region. Some of the limestone masses, such as that forming the tall crags of Malik Gatt and that of the two hills Masanen Chapar and Kasanen Chapar, are of the age of the Cardita beaumonti stage. The sequence in the Malik Gatt, an elongated, tabular hill of horizontal strata, is as follows.[2]

5. Coralline limestone with *Cardita beaumonti* and other fossils ;
4. Shales, often greenish and purple, and frequently interbedded with conglomeratic bands ;
3. Brown or buff limestone with black fossils, the upper portion full of volcanic material;
2. Coarse, almost conglomeratic beds, made up of fragments of volcanic rocks, and full of oyster shells (*Liostraea vredenburgi* Douv.) ;
1. Soft, grey shales full of gypsum veins.

The fossils, which are definitely marine, come principally from Zone 3 but have been collected mostly from loose material ; they include, according to the determinations of Prof. H. Douville,[3]

Ostraea (*Liostraea*) *orientalis* Douv. (Stoliczka's "*O. acutirostris*"),
,, ,, *vredenburgi* Douv.,
Cardita (*Venericardia*) *beaumonti* d'Arch.,
Astarte sp.,
Meretrix (*Callista*) sp.,
Lucina cf. *contorta* Defr. (found in the Palaeocene of Europe,)
Cyprimeria sp.,
Velates haliotis (d'Arch. & H.), (found in the Palaeocene of Ranikot),

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[1] Noetling also mentions "*Cardita subcomplanata* d'Arch. & H. (probably a smaller species), *Corbula* (*Agina*) *harpa* d'Arch. & H. (a species found in the Palaeocene of Rodikot), *Nautiluz subfleuriausianus* d'Arch. & H. rechristened by Douvillé *N. metafleuriausi*, and *N. sublaevigatus* which Spengler has renamed *N. baluchistanensis*.

[2] E. Vredenburg. *Mem.* XXXI, 236-7 (1901).

[3] *Pal. Ind.*, New Ser., Vol. X, Mem. 3, p. 5 (1928).

Calyptraphorus sp.,

Cerithium (*Campanile*) *breve* Douv.,

Nautilus labechei d'Arch. & H. (very close to or prehaps identical with *N. heberti* d'Orb. an abundant form in beds of the same age in Sind).

In the Chapar area, the Cardita beaumonti Beds include a coralline limestone believed to correspond to that capping the Malik Gatt; in this case, however, it is followed by shales, limestone bands and calcareous sandstones interstratified with tuffs and agglomerates and intruded by diorites, and three or four fossiliferous bands. Two of the latter have yielded the following individual assemblages.[1]

KASANEN CHAPAR, LOWER HORIZON—

Pholadomya halaensis d'Arch. (found also in the Lower Eocene of Sind),

Corbula sulcifera Hisl. (an Inter-trappean form; very close to *C. subexorata* d'Arch. from the Laki seris of Sind and the Eocene of Egypt and Somaliland),

Cardita (*Venericardia*) *beaumonti* d'Arch.,

Cyprimeria gigas Douv.,

Semiauricula sp.,

Lunatia (*Gyrodes*) *vredenburgi* Douv.,

Pyrgulifera (*Hautkenia*) *ornatissima* Douv.,

,, ,, *striatocostata* Douv.,

Faunus baluchensis Douv.,

Morgania [*Vicarya*] *fusiformis* (Hisl.) (found in the Inter-trappeans of India; identical with *Irania fusiformis* Douv. from the uppermost horizons of the Cretaceous in Persia)

Pseudoglauconia vredenburgi Douv. (an Eocene melaniid genus in Peru),

Turritella pustulosa Douv.,

,, (*Mesalia*) *fasciata* Lam. (occurs also in Persia),

Cerithium (*Campanile*) *elongatum* Douv.,

,, (*Procerithium*) *millegranum* Münst. (occurs also in Persia),

,, (*Tiaricerithium*) *vredenburgi* Douv.,

Potamides chaparensis Douv.,

,, (*Pyrazus*) *expansus* Douv. (closely related to *Pyrazus stoddarti* Hisl. of Persia and to *P. buddha* Noetl. from Mazar Drik),

,, ,, *stillans* Vida (occurs also in Perisa),

,, (*Terebraliopsis*) sp.

KASANEN CHAPER, UPPER HORIZON—

Cardita (*Venericardia*) *beaumonti* d'Arch.,

Lunatia cf. *cretacea* Goldf. (species found in Europe),

Turritella praelonga Hisl., (an Inter-trappean species),

Faunus mumia Douv.

Morgania [*Vicarya*] *fusiformis* (Hisl.),

Cerithium (*Procerithium*) *triplex* Douv.,

Potamides (*Terebraliopsis*) *diadematus* Douv.,

From the Kan area, a little further north, come the following few additional forms:

Ostraea kanensis Douv.,

Cardita (*Venericardia*) *elliptica* Douv. (abundant),

Cerithium (*Procerithium*) *morgani* Douv. (found also in Perisa),

,, (*Tiaricerithium*) *baluchense* Douv.,

Potamides ernesti Douv.,

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[1] H. Douvillé, *Pal. Ind.* New Ser., Vol. X. Mem. 3. p. (1928).

The beds at Kasanen Chapar are overlain by shales and sandstones with vegetable impressions and an estuarine appearance, recalling some of the Palæocene (Ranikot) beds of Sind.[1] In the Kan area, the Cardita beaumonti beds are followed by olive green shales and limestone bands containing globular forms of alveolines very similar to the flosculines so characteristic of Palaeocene; these shales and limestones, therefore, would appear to be passage beds between the Cretaceous and Tertiary.[2]

The Cardita beaumonti beds of Chagai are of sub-litoral or lagoonal facies. Certain of the species have their analogues in the Parisian Tertiary, but the large size of the *Pyrazus*, *Cyprimeria* and others point to a much warmer climate. Through the *Pyrazus*, *Morgania fusiformis* and *Turritella praelonga*, this stage is related to the Inter-trappeans of Central India.

At Amir-Chah a ridge of "Hippuritic" limestone is both overlain and underlain by flysch strata. A fragment of similar limestone also forms the conspicuous peak known as Sor Koh, west of the recent volcano, Damodim, and rests conformably upon a great accumulation of volcanic strata. All these rocks are profusely injected with basalt[3]. Koh-i-Humai (Koh-i-Rezai), north of Tozgi, consists of large masses of "Hippuritic" limestone, not less than 300 feet thick, resting upon a series of shales, flaggy limestones, calcareous shales, arenaceous shales and arenaceous limestones, all frequently containing volcanic material. West of Koh-i-Humai, around the modern volcano of Koh-i-Dalil, the older rocks of the nearly horizontal succession consist of flysch and limestones of probably Cretaceous age.

Sind.—The only locality in Sind in which beds of older date than Eocene have been identified is the Laki range. To the south-west of Amri on the Indus, some very dark coloured hills form part of the range and contrast strongly with the cliffs of grey and white Nummulitic limestone behind them[4], these dark hills are composed of Cretaceous strata, the lowest member of which is exposed only at the base of Bor Hill. The Laki range here consists of three parallel ridges, the outer and inner of which are made up of the Tertiaries, while the intermediate one consists of Cretaceous beds dipping under the Palaeocene westwards and thrust up against the Lower Eocene to the east.

The lowest member of the Cretaceous succession here is a limestone, the lower portion of which is pure, compact, light-coloured and homogeneous, while the upper is sandy and gritty, often containing ferruginous concretions, and passing up into the overlying sandstones. The limestone is fossiliferous and contains echinoderms and mollusca, but scarcely any recognisable forms can be extracted therefrom. The basal layers have yielded an *Orbitoides* which Vredenburg identified with the larger and less swollen Maestrichtian *O. apiculata* Schlumb. but which Douville has since renamed *O. vredenburgi*; the latter authority suggests that it plays the same role in India and Tibet as *O. tissoli* does in the Mediterranean basin and, like the Mediterranean species, indicates the basal Campanian[5]. A little over 300 feet of this limestone are exposed but its base is not seen, the length of the outcrop being less than half-a-mile. It occupies much the same stratigraphical position as the Hemipneustes Beds of Baluchistan.

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[1] Gen. Rep. 1900-01, 31.

[2] Henry Douville *Pal. Ind.*, New Ser., Vol. X, Mem. 3, 6-7 (1928).

[3] E. Vredenburg. *Mem.*, XXXI, 249-250 (1901).

[4] W. T. Blanford. *Mem.*, XVII, 33 (1879).

[5] *Pal. Ind.*, New Ser., Vol. V, Mem. 3, 32 (1916). A specimen of *Hippurites* is recorded from this limestone but has been lost; no further examples of this genus could be found by Vredenburg.

The upper gritty layers of the limestone just described pass up into sandstones, conglomerates, dark gritty limestones, and ferruginous bands, all weathering to a very dark colour, and capped by a thick bed of dark impure limestone containing ill-preserved oyster shells and occasionally large bones, apparently of reptiles. In one place a 40-feet bed of basalt is seen interbedded in the sandstones, but may be an intrusion. This stage, with a total thickness of about 800 feet, corresponds to the Pab Sandstone and passes up into the overlying subdivision.

The upper stage consists of about 500 feet of soft olive shales and fine sandstones, the latter thin and containing volcanic matter : rarely, thin layers of dark olive or drab impure limestone are seen. The shales commonly contain gypsum and many fossils, the latter principally in two bands separated from each other by 100 feet of barren starta. Most of the fossils come from the lower band, where the type fossil, *Cardita* (*Venericardia*) *beaumonti* is found in hundreds, in excellent preservation and often with the valves united. In addition are well preserved specimens, most of them from Jakhmari, of the following corals and echinoids :[1]

Anthozoa—
- *Caryophyllia compressa* Dunc.,
  - ,, *indica* Dunc.,
  - ,, *feddeni* Dunc.,
- *Trochocyathus lakii* Dunc.,
- *Smilotrochus jakhmari* Dunc.,
  - ,, *blanfordi* Dunc.,
- *Stylophora* sp.,
- *Calamophyllia* (*Rhabdophyllia*) *barkii* (Dunc.),
- *Litharaea pithecata* Dunc.,
  - ,, ,, var. *hemisphaerica* Dunc.

Echinoidea—
- *Cidaris lacrymula* Dunc. & Sl.,
- *Plesiolampas elongata* Dunc. & Sl.,
- *Echinanthus pumilus* Dunc. & Sl. (a variety of this species has been recognised in the Mæstrichtian of 'Oman),
- *Linthia sindensis* Dunc. & Sl.

In addition there occur two common forms of *Ostraea*, one of them a very abundant species identified as *O.* (*Liostraea*) *orientalis* Douv., the other as *O. preflemingi* Douv., *Lima* cf. *obliquistriata* Forb. (an Ariyalur species), *Crassatellites austriaca* (Zitt.) (found in the Olive Shales of Baluchistan, in the Gosau of Saxony in the Danian of 'Oman and Persia, and in the Palæocene of Sind), *C. macrodonta* (Sow.) (an Ariyalur and Gosau species), *Callista* (*Callistina nuttalli* Douv., *Cytherea* (*Caryatis*) *abbreviata* Douv., *Cardita* (*Venericardia*) *vredenburgi* Douv. (a mutation of the commoner *C.* (*V.*) *beaumonti*), *Pholadomya holaensis* d'Arch., *Cardium inaequiconvexum* Vred. (closely related to the Olive Shales species *Cd. loralaiense*), *Coralliophaga* (?) *indecisa* Cossm. & Piss., *Cyrena* (?) *haydeni* Vred., *Panope* [*Glycimeris*] *vredenburgi* (Cossm. & Piss.), *Corbula* (*Agina*) *harpa* d'Arch. & H. (found in the youngest of the Baluchistan Cretaceous zones and ranging up into the Palæocene ; Douvillé classifies the Sind specimens into two varieties, *trigona* and *brevis*). Professor Douvillé has identified several gastropods,[1] none of which is very characteristic,

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[1] *Pal. Ind.*, Ser. VII & XIV, Vol. I, Pt. 2, p. 16 (1880). *Ibid* Pt. 3, p. 7 (1886).

Gastropoda—
Littorina morgani Douv.,
Euspira [*Naticina*] *nuttalli* (Douv.),
Gyrodes sp.,
Confusiscala indica Douv.,
Turritella (*Mesalia*) *fasciata* Lam.,
,, (*Haustator*) *congregata* Douv.,
,, ,, *nœtlingi* Douv.,
,, (*Torquesia*) *nuttalli* Douv.,
,, (*Turricula*) *vredenburgi* Douv.,
Cerithium (*Bellardia*) *indicum* Douv.,
,, ,, *vicinum* Douv.,
,, (*Exechocirsus*) *graniferum* Douv.,
Cerithium (*Campanile*) *morgani* Douv.,
,, ,, *breve* Douv.,
Terebralia vredenburgi Douv.,
Potamides (*Pyrazus*) *stoddardi* Hisl., var. *curta* Douv.,
,, ,, *nuttalli* Douv.,
,, (,, ?) *vishnu* (Nœtl.),
,, (,, ?) *buddha* (Nœtl.),
Cyclomolops vredenburgi Douv.,
Semicassis indicus Douv.,
Cypræorbis [*Bernaya*] cf. *expansus* (d'Arch. & H.),
,, ,, *globus* Douv.,
Ancilla vetusta (Forb.), (an Ariyalur species),
Pseudoliva robusta Br. & Corn., race *indica* Douv. (*forma typica* found in the Palaeocene of France),
,, *canaliculata* Br. & Corn. (*forma typica* found in the Palæocene of France).
Athleta (*Volutocorbis*) *indica* Douv. (common),
Hemifusus (*Mayeria*) *nodulosa* (Stol.), (an Ariyalur species),
Heligmotenia cf. *molli* Douv. (species found in the Sudan and Senegal),
Eovasum indicum Douv.,
Preslrombus vredenburgi Douv.,
Diploconus elegans Douv.,
,, *crassus* Douv.,

The following cephalopods are also recorded :
Nautilus forbesi d'Arch. & H.,
,, *blandordi* Douv. (closely allied to *N. heberti* d'Orb. from the Danian of Paris),
,, *metafleuriausi* Douv. (possibly from a post-Danian horizon ; resembling the Sind Palæocene species *N. deluci* d'Arch.),
,, *labechei* d'Arch. (horizon somewhat doubtful),
Eutrephoceras sublaevigatum (d'Orb.), var. *indica* Spengl. (found in the Ariyalur beds of Pondicherry).

In the lower part of the Cardita beaumonti beds there have been found some amphicœlous crocodilian vertebræ said to resemble the Wealden *Suchosaurus*.[2] *Cardita beaumonti* itself is extremely abundant in one bed about 200-250 feet below the top of the stage, but is not confined to this horizon. Above the olive shales with *Cardita beaumonti* comes a band of Deccan Trap basalt, probably intrusive, followed by the Palæocene sandstones and clays in great thickness, exposed on the slopes of the main range and capped by the Kirthar (Middle Eocene) limestone.[1]

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[1] *Pal. Ind.*, New Ser., Vol. X, Mem. 3, Fasc. 2 (1929).

[2] W. T. Blanford *Mem.*, XVII, 35 (1879).

The most striking feature of the Cardita beaumonti fauna in Sind is its definitely marine character; in this it contrasts with that of Baluchistan where the beds appear to have been almost brackish. According to Douvillé, the Sind beds belong to a slightly higher horizon than the Baluchistan. It will be noticed that a large number of the Sind species, especially among the gastropods, are new; the Fusidæ are characterised by some rapid δ mutations, involving the creation of two new genera.

THE SULAIMAN RANGE.

The section in the Fort Munro area of the Sulaiman range, west of Dera Ghazi Khan, has a general similarity to that seen in the Marri hills and in Jhalawan. In the Rakhi gorge, the core of an anticline is occupied by the oldest beds exposed near Fort Munro; these consist of dark shales and grey limestones corresponding to the Hemipneustes Beds and Olive Shales, of which about 700-1,000 feet are visible. From these have been collected[2],

Orbitoides media d'Arch.,
,, cf. *apiculata* Schlumb. (probably *O. vredenburgi* Douv.),
Lepidorbitoides socialis (Leym.),
Holectypus baluchistanensis Nœtl.,
Echinanthus griesbachi Nœtl.,
Hemipneustes compressus Nœtl.,
Exogyra sp., (probably the Egyptian *E. overwegi* v. Buch, found also in Europe and in the Mæstrichtian of 'Oman,)
A gastropod which is probably *Semisolarium* of the group *S. moniliferum* (Mich.) from the European Gault and *S. karapaudense* Stol. from the Ariyalur stage of southern India.
Species of *Natica* or *Crommium*,
A badly preserved *Pyrgulifera* [*Hautkenia*] comparable to *P. striata* Douv.,
Two specimens of an indeterminate *Cardium* resembling but not identical with *C. harnaiense* Nœtl.

In the Rakhi gorge, above the Hemipneustes Beds, come the Pab sandstone which here attain a thickness exceeding 2,000 feet and contribute the bulk of the section. They are white in colour but weather to a black crust; the extensive blackened surfaces of the bedding planes dipping steeply eastwards produce a peculiar and characteristic appearance. Most of the sandstones are massive but some of the layers show a tendency to become shaly, the result being the dark, flysch-like facies which intrudes itself into so much of the sequence in Baluchistan, as for instance, the Upper Cretaceous (Pab Sandstone), the Ypresian and Lower Lutetian (Ghazij Shales), the Lower Lutetian (Lower Kirthar), and, more especially, the Oligocene (Nari, Kojak) and Miocene (Gaj, Makran, Murree, etc.). Some of the flysch-like layers have yielded the curious pseudo-fucoid impressions known under a variety of generic names such as *Tænidium*, *Caulerpa*, *Phymatoderma*,

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[1] W. T. Blanford. *Mem.*, XVII, 133 (1878).

[2] E. Vredenburg. *Rec.*, XXXVI, 251 (1907). *Ibid.*, LXII, 19-20 (1929); collected by Mr. E. T. Vachell and examined by Dr. Cotter.

Harlania and *Arthrocyphus.* Among these are specimens closely resembling Fuchs' *Caulerpa* (*Phymatoderma*) *arcuata* Schimp. from the Cretaceous flysch near Florence and an unnamed species figured by Fuchs.[1] In addition to these impressions which, according to Nathorst, may be annelid burrows showing transverse wrinkles cased by rhythmical contractions of the worm, there is an excellent example of the markings which have been classified under the Chordophyceæ and are, in the opinion of Nathorst, tracks caused by swimming crustaceans ; the specimen in question is almost identical with the track of *Crangon vulgaris* experimentally obtained by Nathorst.[2] Such markings are said by Mr. H. J. Maynard to be abundant at certain zones of the Cretaceous flysch in Sind. From talus blocks coming from an unknown horizon in the Pab Sandstone of this area Vredenburg has identified *Orbitoides minor* Schlumb., an abundant foraminifer in the Niniyur stage of southern India, as we have seen.

Resting upon the Pab sandstones in the Rakhi gorge section are black sandstones crowded with fragmentary fossils and full of volcanic material, signalising the commencement of the Deccan Trap period. These are succeeded by a lateritic layer which is best regarded as the basal member of the Tertiary and underlies the Dunghan Limestone ; this almost black *Alveolina* limestone, with later members of the Palæocene-Eocene succession, is arranged in minor ridges along the eastern limb of the anticline. The lateritic bed has yielded a few interesting fossils which in reality probably belong to the Cretaceous sequence below the junction plane of unconformity signalised by the laterite though not visible in any change in dip or strike. The fossils appear to have been pseudomorphed by the iron oxide of the laterite, and include : a trilocular fruit with more than one ovule in each loculus, axile placentation and suspended seeds ; corals belonging to an unknown species of *Trochosmilia* ; and the small chambered nucleus of a *Nautilus.*

In the more northerly portion of the Sulaiman range known as the Shirani hills, older beds make their appearance. Below the Hemipneustes Beds with *Orbitoides media* and a maximum thickness of 1,000 feet, and separated therefrom by a wide time gap, are members of the Lower Cretaceous. These comprise the thin-bedded, belemnite-bearing Parh limestones (Hauterivian) overlying the Belemnite Shales (Valanginian-Hauterivian). In the Toi river, the maximum thickness of the Parh limestones and Belemnite Shales together is about 1,500 feet[3] in the Shingu river also these beds are found in full force, but north of this point they become gradually thinner until in the Lohara watercourse they are reduced to about 200 feet and in the Zao section absent altogether.

The beds overlie the massive limestones believed to be Jurassic and consist at the base of black shales from which belemnites weather out though not in large numbers except from certain horizons. Further up come bands of bluish and greenish, thin-bedded limestones, of very uniform thickness and interstratified with the shales ; near the top the limestone bands, in which belemnites can be seen embedded, become thicker and whiter. The limestones of this Parh stage build up a conspicuous ridge parallel to the Takht-i-Sulaiman. The Pab stage consists of hard, quartzose sandstones, nearly 1,000 feet thick, bluish white in colour, weathering to a warm brown. They are generally thin-bedded and contain thin bands of shale, some of which are carbonaceous. Near the base of the sandstones occur the oil seepages of Moghal Kot. Fossils, mostly sections of bivalves, occur sparingly in the basal horizons of this stage, and near the top is a band containing an abundance of oysters. The Pab sandstones are capped by 250 feet of a very hard, grey, massive limestone, which is the Dunghan Limestone at the local base of the Tertiary. In other parts of the range, the Pab Sandstone is described as a massive white quartzite separated from overlying Nummulitic shales by a band of pseudoconglomeratic limestone—a crush conglomerate—precisely similar to that at the top of the Dunghan Limestone in the Marri hills.

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[1] *Denkschr. d. Kais. Akad. d. Wiss. math.-naturw, Classe*, Vol. LXII, Pl. ix, figs. 1 & 2 (1895).

[2] *Ibid.*, Pl. I, fig. 3.

[3] T. D. La Touche. *Rec.*, XXVI, 82 (1893) : corrected in Rec., XXXVI, 252 (1907)

SOUTHERN WAZIRISTAN.

In the Takki Zam valley, in the eastern part of Southern Waziristan, between Kaniguram and Jandola, the Cretaceous occupies a broad belt between the Janjal Plant Beds (? Jurassic) and the Nummulitic shales and sandstones.[2] It consists of olive green and dull chocolate-red shales, with harder calcareous bands and occasional brown sandstones weathering black. In one section thin partings of black limestone and a thick band of reddish brown nodular limestone are recorded. At the top of the exposure, near Mandanna Kach, are some bright purple-red shales and white, gypseous, porcellaneous clays; associated with the latter are some hills of black earth of doubtful origin and obscure relationship.

The olive-green and chocolate-red shales have yielded at certain horizons abundant belemnites, of which the commonest are *Belemnites* (*Hibolites*) *subfusiformis* Rasp. and its variety, *baluchistanensis* and *B.* (*Duvalia*) *dilatatus* Blainv., two of the most frequent fossils of the Belemnite Beds of Baluchistan; these beds, therefore, belong to the Neocomian. In the Waziristan campaign of 1919-1920, the discovery of these belemnites was responsible for the rumour that the Mahsuds were using stone bullets. The upper bright red and white beds, from their striking coloration, have resemblances to part of the Parh stage which they probably represent.

A little further south, in the Shahur gorge, the lower beds are described by Coulson as comprising reddish shales and clays with occasional belemnites and intercalations of marl, and a stage composed of grey clays and shales with marls, sometimes with lignite, and containing abundant belemnites and more than one species of the radiolarian genus, *Cenosphera*.[3] Above these beds come firm sandstones, gritty and calcareous in places, and perhaps the equivalent of the Pab Sandstone; if this correlation should prove correct, there must exist a wide gap in age between these and the belemnite bearing beds below.

In the western half of Southern Waziristan, the lower part of the Cretaceous sequence consists of belemnitiferous green shales, cropping out in the Danawat valley, and apparently grading down into a stage of black shales with ferruginous concretions, obscure plant remains, but no belemnites; these shales are the upper part of Stuart's Janjal Plant series. The topmost Cretaceous here takes the form of massive limestones, giving rise to a very prominent feature and covering a large area; they are developed in the Sura Ghar and at Ghat Ghundai, and are thought by Coulson[4] to belong to the Lower division of the Cretaceous system.

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[1] Gen. Rep. 1901-02, 28.

[2] M. Stuart. *Rec.* LIV, 91 (1922).

[3] J. Pia. *Rec.* 72, 72 (1937).

[4] *Rec.* 73, 84 (1938).

BANNU DISTRICT.

A short distance southeast of Pezu in the district of Bannu, belemnites of the type of *Hibolites subfusiformis*, accompanied by a *Cymatoceras* and a few crioceratid fragments, have been collected, and indicate the presence at this locality of the Belemnite Shales.[1]

THE SAMANA RANGE, KOHAT.

Between Kohat and Thal, in the Samana range, the Jurassic limestone of Samana Suk is succeeded by Cretaceous beds which have been subdivided by Col. L. M. Davies as follows :

5.	Upper lithographic limestone	150 feet.
4.	White quartzitic sandstones, and in places soft olive clays .	0—90 ,,
3.	Lower lithographic limestone	150 ,,
2.	White quartzitic sandstones, variegated with ferruginous layers, with phosphatised fossil casts in the uppermost 5 or 6 feet	700 ,,
1.	Glauconitic sandstone . –	30—50 ,,

The glauconitic sandstone is in places crowded with indeterminable belemnites and generally marked out by the relatively denser vegetation it carries.[2] It appears to be a reduced representative of the Belemnite Shales. This conclusion receives unequivocal support from the discovery by Col. L. M. Davies, in a similar bed near Thal, thirty miles to the west, of an ammonite related to *Holcostephanus* (*Rogersites*) *astierianus* (d'Orb.) and named by Dr. Spath *H.* (*R.*) *salinarius* indicating the Hauterivian sub stage of the Neocomian.[3]

Next come 700 feet or more of white, coarse-grained, quartzitic sandstones, with red, yellow or purple, ferruginous layers, imparting an ornamental aspect to the rocks. For about 200 feet towards the middle of the stage, the sandstones are massive and flaggy with thin clay partings, and give origin to a scarp. Near the top, the white sandstones merge upwards into about 30 feet of greenish sandstone which becomes very coarse and gritty. The uppermost 5 or 6 feet of this sandstone, with its large rounded quartz grains, has occasional thin yellow calcareous bands, and is often crowded with phosphatic fossil casts which, by their dark colour, make the horizon a conspicuous datum line. Glauconite is also found here. The fossils are for the most part very badly preserved ; the principal one, fragments of which occur in great abundance, is the ammonite *Douvilleiceras mammillatum* (Schloth.). The following identifications have been made :

Echinoidea[4]—

Discoidea aff. *decorata* Desor. (the commonest echinoid ; species found in the Albian of France, the Aptian of other parts of Europe, and the Urgonian of Asturias),

Conulus sp.,

A form congeneric with d'Orbigny's *Echinocorys grasanus* from the Neocomian of Isère, *Holaster* sp.

Brachiopoda[5]—

Rhynchonella samanensis Muir-Wood,
,, *reticulata* Muir-Wood,

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[1] *Pal. Ind.* New Ser., Vol. XXV, Mem. 7, 136 (1939).
[2] L. M. Davies. *Pal. Ind.* New Ser., Vol. XV, Pt. I. p. 6 (1930).
[3] *Ibid.*, Pt. V, p. 58 (1930).
[4] by Dr. Ethel D. Currie.
[5] Miss H. M. Muir-Wood.

Brachiopoda (Miss H. M. Muir-Wood)—*contd.*

Terebratula samanensis Muir-Wood,

,, ,, var.,

,, *daviesi* Muir-Wood,

Kingena spinulosa Morr. (an English Gault species),

,, *tumida* Muir-Wood,

Zeilleria sp.

Lamellibranchiata (Dr. L. R. Cox)—

Pecten (s. lat.) cf. *beaveri* J. Sow. (species ranging from the Upper Gault to the top of the Cenomanian in England),

,, [*Neithea*] sp.,

Venus (s. lat.) sp.,

Cyprina cf. *quadrata* d'Orb. (species found in the Cenomanian of Europe).

Gastropoda (Dr. L. R. Cox)—

Trochus (s. lat.) sp.,

Cerithium (*Metacerithium*) cf. *ornatissimum* (Desh.) (European species),

Turritella sp. (related to the Cenomanian *T. neptuni* Münst. of Europe),

Aporrhais (s. lat.) sp. (recalling the widespread Gault species, *A.* (*Perissoptera*) *parkinson* (Mant.) from England),

Vanikoropsis cassisiana (d'Orb.) (found in the Cenomanian of France),

Semisolarium moniliferum (Mich.) (found in the Albian of France).

Ammonoidea (Dr. L. F. Spath)—

Pictetia cf. *astieriana* (d'Orb.) (may be identical with the English species, which has not been found outside the *dentatus* zone),

Desmoceras latidorsatum (Mich.) (found in the Albian of Hazara, and in the Albian and Lower Cenomanian of Europe),

Cleoniceras daviesi Spath,

Douvilleiceras mammillatum (Schloth.) (found also in the Albian of Hazara),

Hysteroceras sp. (a genus more typical of the Upper than of the Middle Albian),

Brancoceras indicum Spath,

Hamites cf. *attenuatus* J. Sow. (similar comparable forms found also in the Albian of Hazara, the species is a European one, and probably occurs in the Upper Albian of Portuguese E. Africa),

Torneutoceras sp. (comparable forms occur in the Albian of Hazara),

Protanisoceras sp.

The ammonites are described as having a curiously strong resemblance, in matrix and in preservation, to the similarly phosphatised ammonites from the *mammillatum* bed in Kent: the assemblage of the Samana range, however, is that of corresponding deposits in more southern latitudes.[1] The ammonites point definitely to a Middle Albian age. This phosphatic fossil band and the white quartzitic sandstones beneath it correspond to the upper and larger portion of the Giumal Sandstone of Hazara, Attock and the Himalaya.

Above the fossil band succeed 150 feet of light-coloured flaggy limestones, so fine-grained and homogeneous in texture as to be often lithographic. There is no visible unconformity between the two stages but the change is abrupt and according to Col. Davies, the lowest few inches of the limestone sometimes contain embedded fossils derived from the beds below with portions of the matrix adhering thereto. No indigenous fossils have been recorded.

The limestone stage described above is in some places separated from another very similar one by a thin band of strata which, in the middle of the Samana range, comprise 50 feet of white quartzitic sandstones of the same type as stage No. 2 except that they are often speckled with rusty spots; in the south of the range this stage includes 20 or 30 feet of the sandstones surmounted by 30-60 feet of soft olive clays.

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[1] Spath. *Pal. Ind.* New Ser., Vol. XV, Pt. v, p, 51 (1930).

The upper lithographic limestone is of the same character and thickness as the lower, but darker and more massive. In some places the two lithographic limestones are found one above the other, the sandstones and clays of stage 4 being absent. The age of the unfossiliferous succession including the two Lithographic limestones is not known. Some facies of the Lower Lithographic Limestone have been compared with the Parh Limestones of Baluchistan which, must be much older. The Lithographic limestone succcession may correspond to some portion of the Chikkim series of the Himalaya, but this is no more than conjecture.

THAL, KOHAT.

An ammonite collected from the mountain of Kadimak, on the western frontier of Kohat near Thal, has been named by Dr. Spath *Holcostephanus salinarius*, and indicates the presence of the Hauterivian in this region[1].

In a pebble from a conglomerate occurring beneath the Palæocene (Ranikot) near Thal, a foraminifer identified by Col. L. M. Davies as *Omphalocyclus macropora* (Lam.) has been obtained, proving the existence in the neighbourhood of the Upper Cretaceous (Danian).

TIRAH.

North of the Samana range, at the junction of the Khanki and Kandi rivers, the lowest beds of the Cretaceous are again seen; further north they are faulted against a white quartzitic sandstone. Proceeding in the same direction, Cretaceous beds are seen on the Sampagha (Sanpagha) Pass, where they are almost horizontal. In the Mastura valley they consist of sharply folded, hard, unfossiliferous limestones, which continue northwards to the Arhanga Pass, where they show the same folding. About two-and-a-half miles north of the pass, the limestones have yielded numerous fossils, chiefly unidentifiable belemnites and brachiopods, including a *Terebratula* which is probably *T. biplicata* Sow., var. *dutempleana* Stol.; above them is an 18-inch. band of soft, rotten, bright red, ferruginous sandstone containing casts of belemnites and fragments of other cephalopods. Similar beds have been found further north in the Waran valley where the fossils are better preserved and include locally numerous shells of *Ostraea*. The brachiopods, according to Nœtling, are forms typical of the Cenomanian of Europe; amongst them Dr. Cotter identifies a *Rhynchonella* close to the Utatur species *R. mutua* Stol. and *Terebratula biplicata*, Sow. var. *dutempleana* Stol.[3] From the Maidan valley the Cretaceous rocks extend northwards and are well exposed in the narrow defile which stretches for some eight miles from Bagh to Dwatowi (Dw-Toi) in the Bara valley. Throughout this gorge the beds are nearly vertical, but are probably repeated several times by the intense folding to which the area has been subjected. The rocks strongly resemble those seen on the Samana range, except that they are much faulted. Three-and-a-half miles north of Bagh, the formation is brought into abrupt contact with the crushed red shales and grey limestones of the Rhætic.

THE SALT RANGE AND ITS TRANS-INDUS CONTINUATION.

In the Salt Range of the Punjab, the Baroch Limestone stage, which appears to be the highest member of the Jurassic present, is succeeded by the Belemnite Shales containing a copious fauna of Neocomian belemnites and ammonites. The shales, with their dark green to blue-black colour, show a marked contrast to the subjacent light-coloured Jurassic limestones, and are described by Mr. Gee (Private communication) as forming a conspicuous band along the upper scarp slopes of the trans-Indus Maidan range. They first appear above the thin Baroch limestones in the slopes west of Sakesar in the cis-Indus Salt Range, and it was from beds in the southern shoulder of this mountain that Professor H. G. Seeley identified, among the more abundant of the well preserved fossils, *Spondylus subcostulatus* Stol., *S. calcaratus* Forb., *Hinnites andurensis* Stol. and *Lucina* (*Myrtea*) *arcotina* Stol., all of these species found in the various stages of the Upper Cretaceous of southern India.[1] Further to the northwest the beds die out for some miles but reappear in the Tredian hills, attaining a thickness of 150 feet opposite Daud Khel, where they have been described as resting upon the eroded Jurassic limestones containing species of *Nerinea* and *Rhynchonella* (*Stolmorhynchia*) cf. *trilobat* Ziet.[2] According to Koken, the section near Daud Khel is as follows :

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[1] *Q. J. G. S.*, LXXXIII, 262, Note 1 (1927); *Pal. Ind.*, New Ser., Vol. XXV, Mem. 1, p. 13 (1939).

[2] *Mem.* XVIII, 103 (1898)

[3] *Rec.* LIX, 408 (1926).

Eocene limestones—

Hæmatitic marl of Palæocene or Eocene age	6—7 feet.
White sandstone with brown markings	32 ,,
Glauconitic and oolitic ferruginous marl with *Hoplites* sp. . . .	10 ,,
Yellowish green sandy marls with *Belemnites* (*Hibolites*) *subfusiformis* Rasp. and *Hoplites* (*Neocomites*) *neocomiensis* d'Orb.	32 ,,

The lowest beds with the lowest Hauterivian zone fossil, *Hoplites neocomiensis*, a form found in the Lochambel beds of the Spiti Shales in the Himalaya, evidently belong to the same levels of the Neocomian as the glauconitic sandstone of the Samana range, while the succeeding white sandstone is lithologically not unlike the Samana stage 2, which is a white quartzitic sandstone with Albian fossils. The hæmatitic marl belongs to the basal Tertiaries (Palæocene or Eocene) and not to the *Cardita beaumonti* horizon, as Koken surmised ; the gap between it and the white sandstone below may include the whole or greater part of the Upper Cretaceous. A similar reddish layer is found at the base of the Tertiary sequence in the eastern part of the Salt Range, where neither Jurassic nor Cretaceous deposits are known. There appears to be no definite record of the finding of *Cardita beaumonti* in either the cis-Indus or trans-Indus Salt Range.[3]

On the other side of the Indus, the Belemnite Shales crop out just north o Kalabagh and at Kuch. Further west and south, in the Maidan range, they form a more or less continuous exposure. In the well known Chichali Pass they include sandy shales and argillaceous sandstones at the top and attain a thickness of 210-240 feet, whilst in the Baroch gorge, west of Mulla Khel, the total thickness of the stage is nearly 400 feet. In the latter locality some of the sandstones are glauconitic and the basal beds have yielded a few pieces of fossil wood as well as cephalopods. Near Makarwal colliery, the beds pitch southwards beneath younger strata ; they have not been recognised in the Khasor hills but appear to be represented by some thin shales beneath the Tertiaries (Siwaliks) of Shekh Budin hill.[4]

In the Maidan range especially, the beds are highly fossiliferous and 120 species of ammonites and belemnites, largely from these hills but partly from the Daud Khel and other localities, have been described by Dr. L. F. Spath.[5] Of these 29 were new at the time of identification, 48 were more or less doubtful determinations, while only 7 belonged to known forms. The seven known forms were :

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[1] *Rep. Brit. Ass.*, LXXII, 604 (1902); also *Geol. Mag.*, IX, 471 (1902).

[2] *Centralbl. f. Min.* etc. (1903), 442.

[3] *Rec.* XLIX, 152 (1918).

[4] The section on the Salt Range Cretaceous is based largely on information very kindly supplied by Mr. E. R. Gee.

[5] *Pal. Ind.* New Ser., Vol. XXV, Mem. 1 (1939).

Neolissoceras grasianum (d'Orb.) (a well known and widespread species with a long range from the Infra-Valanginian to its maximum occurrence in the Hauterivian),
Holcostephanus (*Rogersites*) *schenki* (Oppel.) (a zone fossil of the uppermost Valanginian)
Parandiceras (?) *theodorii* (Oppel.),
Neohoploceras submartini (Mallada),
Belemnopsis gerardi (Oppel.),
Hibolites subfusiformis (Rasp.),
,, *pistilliformis* (Blainv.).

Among the less certain determinations are :

Holcostephanus cf. *drumensis* (Sayn) Kilian,
,, cf. *perinflatus* (Math.),
,, cf. *madagascariensis* Lem.,
,, (*Rogersites*) cf. *atherstoni* (Sharpe),
Spiticeras (*Negreliceras*) aff. *subnegreli* Djan.,
Blanfordiceras aff. *wallichi* (Gray),
,, cf. *acuticosta* (Uhlig),
,, cf. *bœhmi* (Uhlig),
,, aff. *latidomus* (Uhlig),
Subthurmannia cf. *lorensis* (Lisson),
Himalayites cf. *seideli* (Oppel.),
Neocosmoceras cf. *sayni* (Simion.),
Thurmannites cf. *pertransiens* (Sayn),
,, cf. *pronecostatus* (Felix),
Neocomites aff. *platycostatus* Sayn,
,, cf. *teschenensis* (Uhlig),
,, cf. *noriciformis* (Hohen.) Uhlig,
,, aff. *neocomiensiformis* (Hohen) Uhlig,
,, (?) cf. *scioptychus* (Uhlig),
,, (*Odontodiscoceras* ?) cf. *montanus* Uhlig,
Kilianella cf. *pexiptycha* (Uhlig),
,, (?) (*Acanthodiscus*) cf. *lamberti* (Sayn),
Sarasinella aff. *campylotoxa* (Uhlig).

The 29 new species were :

Pterolytoceras (?) *punjabense* (Folgn.) Spath,
Holcostephanus salinarius Spath,
,, *globosus* Spath,
,, *glaucus* Spath,
,, *fascigerus* Spath,
,, *victoris* (Folgn.) Spath,
,, *sublævis* Spath,
,, *pachycyclus* (Folgn.) Spath,
,, *geei* Spath,
,, *radiatus* Spath,
,, *wynnei* (Folgn.) Spath,
Prioniceras indicum Spath,
Subthurmannia media Spath,
,, *patella* Spath,
,, *lissonioides* Spath,
,, *fermori* Spath,
,, *transitoria* Spath,

Subthurmannia filosa Spath,
,, *pseudopunctata* Spath,
Raimondiceras (?) *salinarium* Spath,
Neocosmoceras hoplophorum (Folgn.) Spath,
Parandiceras rota Spath,
Neocomites similis Spath,
,, (*Calliptychoceras* ?) *pseudovicarius* Spath,
Kilianella asiatica Spath,
,, *besairiei* Spath,
Sarasinella uhligi Spath, (a fine specimen, first described as "*Hoplitides* (*Thurmannites*) *trezanensis* *Sayn*"),
,, *chichalensis* (Folgn.) Spath,
Neohoploceras baumbergeri (Folgn.) Spath.

Folgner also records a vertebra of an *Ichthyosaurus*, some fish remains (*Strophodus*), *Astarte herzogi* Krauss, *Exogyra imbricata* Krauss, *E.* aff. *couloni* d'Orb., and the gastropod, *Pleurotomaria blancheti* (d'Orb.), and Spath, *Pecten* sp. and *Pholadomya* sp. The fossils show signs of having been rolled and are generally much corroded on one side; some of them appear to have been derived from an older horizon. The beds and faunas show marked lateral change, even in short distances. The great majority of the fossils come from the basal portion of the shales. In analysing the faunas from the different localities, Dr. Spath notes that the genus *Subthurmannia* is confined to the Infra-Valanginian. *Blanfordiceras*, also, is essentially Tithonian and not likely to range high into the Neocomian; where not derived, therefore, it is probably confined everywhere to low horizons of the Infra-Valanginian. *Kilianella*, *Sarasinella* and *Neohoploceras* clearly belong to the Middle and Upper Valanginian. As a whole, therefore, the Salt Range assemblage ranges from the Infra-Valanginian (Upper Berriasian) to the top of the Valanginian; there are no definite indications of the presence of the Hauterivian. The fauna has elements in common with the Spiti Shales, some of them at least probably derived, and is closely comparable with similar faunas in Madagascar, the Crimea and the Mediterranean. The representation of the different ammonite zones at the principal localities is diagrammatically shown by Dr. Spath in the following scheme:

Stages and sub-stages.		Zones.	Makarwal.	Chichali.	Kalabagh.	W. Salt Range.	Sakesar.
Valanginian.	Upper	*schenki*	+	+	+	+	?
		verrucosum	+	+	+	+	
	Middle	*roubaudiana*	+	+	+	?	
	Lower	*gratianopolitense*	+		+		
Infra-Valanginian		*boissieri*	+	+			
		callistoides		+			

The Belemnite Shales pass up into what Mr. Gee calls the Lumshiwal Sandstones, named after the coal mine at Makarwal. These massive sandstones, underlying the coal seam of Makarwal, are well exposed in this locality and have furnished a few leaf impressions; one of the intercalated bands of shale has yielded some horny bivalves. In the cis-Indus Salt Range this stage has been found only in the extreme west, *i.e.*, in the northern part of the Tredian hills, opposite Daud Khel, where they are 60-75 feet thick and lie between the Belemnite Shales and the basal laterite of the Tertiaries. North of Kalabagh, across the Indus, these sandstones appear to be absent, but they are well seen further west in the Chichali gorge, varying up to 90 feet in thickness. Southwards in the Maidan range, they thicken and in the Baroch gorge measure about 330 feet. In the type locality of Makarwal, where it includes in its upper part several thin bands of grey and sometimes coaly shale, the stage is about 250 feet thick. In general the sandstones are light grey, yellow or variegated, felspathic, and medium to coarse in texture, with thin bands of carbonaceous or ferruginous shale.

AFGHANISTAN.

Distribution.—Cretaceous exposures are widespread over Afghanistan and occupy a large portion of Afghan-Turkistan. To the west and northwest, beds of this system extend in strip-like outcrops through the province of Herat into the northeastern part of the Persian province of Khorassan, where all stages from Neocomian to the *Exogyra* limestone at the top appear to be present. In the northern and possibly other parts of Afghanistan, there is evidence to show that the middle portion of the Cretaceous is missing. The Afghanistan succession consists of a thick series of red grits surmounted unconformably by an overlapping fossiliferous limestone of Upper Cretaceous age.

Lower Cretaceous.—The Red Grit series, as the lower division was called by Griesbach at Firaiman near Mashhad, overlies some beds yielding specimens of a *Terebratula* which appeared to Hayden to be identical with *T. sella* Sow., a common Lower Cretaceous form in Europe; these specimens occur in a matrix composed largely of *Orbitolina*, and accompanying them was a fragment of what appeared to be a rudistid, possibly *Monopleura.*[1] Assuming this horizon to be approximately Barremian in age, the Red Grit series might date from the Aptian or a younger horizon. In the neighbourhood of Ishpushta, however, Hayden speaks of the plant-bearing Saighan series, probably of Jurassic age, as passing up through brown pebble beds into a great thickness of the Red Grit series, which is here composed of intensely red rocks, chiefly grit, pebbly sandstone and conglomerate. It seems possible therefore, that the Red Grit series may include in places the lowest stages of the Cretaceous. It has been noted in the Chehil and Aokhorak (Khorak) area, in Hajar-Kamard, in Bamian, in lower Saighan and in western Afghanistan. In central Saighan it thins out westwards towards the upper part of the valley; in Begal and Khargin the Red Grit series, together with almost the whole of the Saighan series, has been removed by denudation before the deposition of the overlying Upper Cretaceous limestone. Hayden records the presence of rudistids in a red calcareous bed near the top of the Red Grit series. Gypsum layers occur in places.

Upper Cretaceous.—The Upper Cretaceous of Afghanistan varies enormously in thickness ranging from two or three hundred up to 4,000 feet. It was divided generally by Griesbach into two series, a lower of limestones and earthy shales with foraminifera and Trigoniae, overlying a basal soft grey-green sandstone, and an upper composed of grey coral limestones or greenish earthy limestones, both characterised by species of *Exogyra*, *Pecten quinquecostata* and many other fossils.[2] *Exogyra decussata* Coq. is the most abundant and characteristic fossil in the *Exogyra* limestone, the greater part of which is undoubtedly of Campanian age.

Between Tashkhurghan and Haibak, the Upper Cretaceous is about 2,500 feet thick, lying with no visible unconformity upon the Red Grit beds; south of the latter town, however, there is a marked unconformity and the beds also are seen to be intruded by many trap dykes. Near Tashkhurghan the *Exogyra* limestones are in places porous and chalky and contain strings and nests of flints. The uppermost beds of this area, consisting of limestone and shell breccia with fossils including a large conspicuous *Ostraea*, pass under the Tertiaries.[3]

In the province of Maimana and in Afghan-Turkistan, the uppermost beds are hard, white splintery limestones, concretionary, earthy limestones, occasionally dolomitic, and chalk with flints; *Exogyra* is found in all these horizons and *Inoceramus* sp. in the chalk.

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[1] *Mem.* XXXIX, 34 (1911)

[2] *Rec.* XIX, 252 (1886).

[3] *Rec.* XX, 19 (1887).

Cretaceous rocks occur on both sides of the Hindu Kush, and in great force between the Hindu Kush and Peshawar. Northwards from the Koh-i-Baba and the Hindu Kush to the plains of Afghan-Turkistan, the whole area was formerly covered by a sheet of Upper Cretaceous limestone deposited unconformably on all older formations. The limestone of the Khyber Pass is thought to be the same as the Cretaceous limestone in the Kohat Pass and the Afridi hills south of Peshawar.

From the plain between the Amran range and the Helmand river there crop out at intervals rocks which in the majority of cases consist of the so-called Hippuritic Limestone, a hard, grey, fine-grained rock which in many localities has yielded rudistids, corals and other Cretaceous fossils in abundance. In places it is much shattered and permeated with intrusions of granite and trap, which have frequently altered it to a crystalline limestone much used for ornamental purposes and especially in the construction of shrines, of which the tomb of Ahmed Shah in Kandahar is an example.[1] The granite ridge containing nearly all the passes from the Argandab into the Khakriz valley forms a long "dyke" in the Hippuritic limestone of the district. Below the limestone in the valley north of Kandahar, Griesbach records the following sequence :

3. Shaly sandstone, largely of trappean material ;
2. Green and densely red shales, with thin sandstone beds of trappean material ;
1. Coarse, thick conglomerate, made up almost entirely of pebbles of trap, cemented together by a trappean but calcareous matrix.

In the Herat area, the southern half of the Doshakh range, including the peak itself is built up of the Hippuritic formation which occupies nearly all the hill ranges of southern and western Afghanistan.[2] At the Zingatak Pass, where they are faulted against Palæozoic rocks, the Cretaceous beds are described as containing *Hippurites* accompanied by badly preserved ammonites and bivalves. The Siah Bubak or Paropemisus range is made up of a fractured anticline of Jurassic plant beds, but south of the valley Cretaceous rocks appear, consisting of chocolate-coloured limestones below, perhaps corresponding to the Red Grit series, and grey limestones above. According to Prof. Douvillé, both contain rudistids, and these lamellibranchs are most probably the "*Hippurites*" of early observers. From the lower formation, identified as belonging either to the Lower Cenomanian or perhaps even the summit of the Vraconnian, come :

Eoradiolites cf. *lyratus* Conr. (a form found in the Cenomanian of Lebanon and Egypt),

A small *Sphærulites* recalling "*Agria*",

Another small lamellibranch recalling *Apricardia nœtlingi* Blankh., a species characteristic of the Lower Cenomanian of Lebanon[3].

A large form, grey and therefore quite different in colour from the other fossils, probably derived from the Upper Cretaceous "Coralline limestone with *Hippurites*" or the zone of *Inoceramus balticus*[4] has been determined as *Sphærulites griesbachi* Douv. (one of the forms confounded under the general term of *Hippurites*); it has resemblances to the Cenomanian *S. foliaceus*, the Upper Turonian *S. patera* and the Middle Senonian *S. boreaui*.[5] The limestone and shell breccia with the large conspicuous *Ostræa* found near Tashkhurghan has been recognised also in the Herat neighbourhood.[6] Griesbach's specimens from Herat also include a large indeterminate rudistid and, probably from another horizon, *Eoradiolites* of the group *lyratus* Conr., as well as *Apricardia noetlingi*. The Upper Cretaceous occupies a large area north of Estoi and the Paropamisus range ; here white marly limestones, crushed against the Jurassic sandstones and grits, contain *Inoceramus balticus* Böhm, a lamellibranch found in the Senonian of Europe.

After the deposition of the Saighan series, northern Afghanistan is believed to have formed part of a great land-locked basin in which was accumulated a thick series of conglomerates, grits and sandstones, followed by red limestones with rudistids, indicating a gradual reversion to marine conditions.

Of the Cretaceous faunas of Afghanistan our knowledge is very incomplete. In Upper Saighan some shaly marls and arenaceous limestones, below the *Exogyra* limestone, have yielded echinoids, ammonites and a brachiopod, including *Cyphosoma* sp., *Micraster praecursor* Rowe, *Hoplites* sp. and a few fragments of *Scaphites*, and a Terebratula identical with or very closely allied to *T. semiglobosa* d'Orb. In the limestone above, which is full of *Exogyra*, occur *Gryphœa vesicularis* (Lam.) and *Pecten quinquecostatus* Sow. Some specimens determined by Mr. H. S. Bion come from various parts of Afghanistan, from horizons not definitely known ; they are as follows.[1]

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[1] *Mem.* XVIII, 8, 43 (1881).

[2] *Rec.* XIX, 63 (1886).

[3] *C. R. Soc. géol., France*, 1924, p. 58.

[4] (Griesbach's "*Inoceramus cripsi* Mant." See *Rec.* LVI, 265 (1924).

[5] *Rec.* LVIII, 348 (1925).

[6] *Rec.* XX, 19 (1887).

Cyphosoma sp.,

Micraster praecursor Rowe,

Serpula cf. *gordialis* Schloth. (identical with the specimens found in the Ariyalur of southern India ; species abundant in the uppermost Cretaceous of Europe),

,, *filiformis* Sow. (found also in the Ariyalur stage),

Terebratula (*Concinnithyris*) *obesa* Sow. (an Utatur species ; found also in the Albian, Cenomanian and Turonian of Europe),

,, *biplicata* Sow. (varieties found in the Trichinopoly and Ariyalur stages),

Inoceramus balticus Bohm. (found in the Senonian of Europe, and in the Ariyalur stage),

Gryphaea vesicularis (Lam.) (abundant in the Ariyalur and Niniyur stages of S. India ; found in the Campanian of Europe, and also in N. America, Algiers, Syria, Asiatic Russia and elsewhere),

Exogyra decussata Coq. (found in the Campanian of Europe),
,, *plicifera* Duj. (found in the Lower Senonian of Europe),
,, *ostracina* Lam. (a widely distributed form, abundant in the Ariyalur stage),
Pecten quinquecostatus Sow. (found in the Utatur, Trichinopoly and Ariyalur stages of S. India ; ranging in Europe from the Lower Greensand to the Upper Chalk),
Spondylus calcaratus (?) Forb. (found in the Trichinopoly stage of S. India),
Lima (*Acesta*) *obliquistriata* Forb. (found in the Ariyalur stage of S. India),

Pholadomya cf. *gigantea* Sow. (species found at various horizons ranging from the base of the Cenomanian to the top of the Aptian, in Europe and W. Africa, and in the Barremian (?) of Oman),
Cardium sp.

With one or two exceptions, these fossils would appear to belong to a fauna of Senonian age, most of them indicating the Upper Senonian (Campanian). The chief feature of interest in this fauna lies in its strong affinity not only with the Ariyalur stage of southern India but also with the corresponding assemblage in Europe ; with respect to the latter, the most striking similarity is perhaps shown in the occurrence of the typical Upper Chalk genera, *Cyphosoma* and *Micraster*.

Some large oysters collected by Dr. Fox from the western side of the Shorbaly anticline are comparable to *Exogyra ponderosa* Rœm., a widely distributed Cenomanian species.

CHINESE TURKISTAN.

A similar succession to that found in Afghanistan is seen in the Yarkand area of Chinese Turkistan, where a series of red sandstones is overlain by coarse, grey, calcareous sandstones and chloritic marls, some beds of which are composed almost exclusively of *Gryphœa vesicularis* shells, many of them of enormous size.

RUSSIAN TURKISTAN.

In Russian Turkistan also the Cretaceous, although showing considerable variation, consists where well developed of a great thickness of brightly coloured beds—inconstant layers of gypsum and clay, and more persistent marls, shell limestones, and micaceous and ferruginous sandstone. Two horizons are distinguishable, an upper with numerous species of *Ostraea* and Senonian ammonites, and a lower with rudistids, echinoderms and other fossils. In this region, as well as in Persia and Bahrein Island, the Cretaceous is oil-bearing ; in the last named area the supplies of petroleum are of considerable importance.

EASTERN PERSIA.

The geology of the Persian provinces of Khorassan and Kirman is so closely bound up with that of the adjoining countries of Afghanistan and Baluchistan that the three regions can scarcely be studied apart. A brief sketch of the first, therefore, will not be out of place, especially as so much of the investigation has been carried out and published by the Geological Survey of India.

Cretaceous rocks play an important part in the mountain ranges skirting the northern frontiers of Persia and occupy great ranges in Khorassan. In this province the Upper Cretaceous, which is represented by some 3,500-4,000 feet of strata, contains many fossils and is apparently divisible into a lower portion with *Trigonia* and an upper with *Inoceramus* (described as *I. cripsi* but probably *I. balticus*). *Terebratula sella* Sow. has been identified as coming from Firaiman,[1] while a locality five miles north of this town has yielded *Orbitolina* and a *Pyrina* resembling the Cenomanian *P. desmoulinsii* d'Arch.[2]

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[1] *Rec.* LVI, 260 (1924).

In eastern Persia the Cretaceous Hippuritic limestone rests, sometimes with marked unconformity, sometimes with no visible discordance, upon a series of coloured shales, grits and conglomerates, containing at one horizon plant remains. These coloured beds were found by Mr. Tipper to rest with perfect conformity on brown sandy limestones crowded with belemnites and having a marine fauna of Upper Liassic age.[3] The plant-bearing beds, which have a wide distribution also in northern Persia, are Jurassic and form part of the Saighan series of Afghanistan, as perhaps do many of the coloured strata below and above. The sequence where fully developed is, in fact, divisible into a lower green grit series, comparable in many ways with the Saighan, and an upper corresponding to the Red Grit series of Afghanistan. In Khorassan and perhaps northern Persia, the latter takes the form of a sandstone, mostly reddish brown in colour, often grity and even conglomeratic, which continues into the northern flank of the Hindu Kush and other parts of Afghanistan.[4]

Above the Red Grit beds comes the massive Hippuritic Limestone, widely distributed in Khorassan and Kirman, forming in the north the prominent upper scarps of the hill ranges, if not the hill ranges themselves, and in the south the cores of anticlines. Over most of eastern Kirman the Red Grit formation appears to be missing, the Hippuritic Limestone resting directly and with decided unconformity on the Jurassic plant beds. In eastern Persia this unconformity is a striking one, and implies a long period of folding and denudation before the widespread and marine transgression denoted by the Hippuritic Limestone.

The principal rock of the Hippuritic Limestone is described as a pink or white, massive limestone, but darker varieties occur here and there. Shaly beds are found above and below but never in any considerable thickness. The formation is generally fossiliferous, the commonest form being *Hippurites* which in places can be collected in large numbers. Several species of *Hippurites* and other rudistids are present. Among them the following, coming mostly from the locality of Badamu, to the west of Kirman, have been described by Prof. Othmar Kühn, and merit recording here since many of them may ultimately be found not only in Afghanistan but also in Baluchistan.[5]

Hippurites (*Vaccinites*) *chalmasi* Douv. (found in the Santonian-Campanian of Europe),
,, ,, *conicus* Kühn (having Senonian affinities),
,, ,, *corbaricus* Douv. (found in the Coniacian of southern France),
,, ,, *rousseli* Douv., var. *batnensis* Douv. (species found in the Lower Santonian of Algeria),
,, ,, *vesiculosus* Woodw. (found in Asia Minor and in the Campanian of Egypt),
,, ,, *vredenburgi* Kühn (Vredenburg's "*H. gosaviensis* Douv."; an abundant species close to the Coniacian *H. giganteus* d'Orb.),
,, (*Orbignya*) *tipperi* Kühn (resembling the Santonian *H.* (*O.*) *toucasi* d'Orb. and *H.* (*O.*) *carezi* Douv.),
,, (*Hippuritella*) *cornucopiae* Defr. (recorded also from Luristan, and from the Mæstrichtian of Italy and Sicily),
,, ,, *grossouvrei* Douv. (found in the Upper Angoumian of France and Lebanon),
,, (*Pironaea*) *persica* Vred. (found also on the N. W. margin of the Seistan swamp near the Persian-Afghan frontier),

Eoradiolites cf. *lyratus* (Conr.) Douv. (badly preserved),

Radiolites (*Durania*) *inermis* Douv. (found in the Turonian of Sinai),
,, ,, *laevis* Douv. (found in the Cenomanian of Syria),
,, ,, *major* Kühn (similar to the European *R.* (*D.*) *cornupastoris* (Desm.),
,, (*Osculigera*) *cleggi* Kühn (genus belonging to the Senonian family of the Lapeirouseiinæ),
,, ,, *hippuritiformis* Kühn,
,, ,, *magna* Kühn.

In addition to these rudistids, the following forms have been recorded by Pilgrim, Tipper, Bion and Cox: *Orbitolina* cf. *concava*, *Patellina* sp., *Holectypus* sp., *Pyrina* aff.

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[1] H. S. *Rec.* LVI, 264 (1924).

[2] *Rec.* XXXVI, 314 (1907).

[3] *Rec.* LIII, 57 (1921).

[4] *Mem.* XXIII, 82 (1891).

[5] *Rec.* LXVI, 151 (1932).

vionetti Desor, *Salenia* aff. *grasi* Cott., species of a new echinoid genus resembling *Epiaster*, *Sphaerulites* sp., *Radiolites* (*Durania*) sp., *Exogyra* cf. *matheroni*, a large *Nerinea Trochactaeon* cf. *gigantes* Sow. (probably a Senonian form), *Trigonia* sp., *Pecten* sp., and *Terebratula sella* Sow.; *Exogyra conica* Sow. comes from an older stage north of Baghin. The echinoids, which are all exceptionally large, come from the base of the massive limestone and have Cenomanian affinities. Of the rudistids, which are always regarded as of important stratigraphical value, one is Cenomanian, two are Turonian, four Senonian, and one Danian, the rest being of less certain horizon. The best represented stage, therefore, is undoubtedly the Senonian. From the presence of the Mæstrichtian *Hippurites cornucopiæ*, the Hippuritic Limestone of these parts would seem to range beyond the top of the Senonian.

In Kuhistan the Hippuritic rocks are traversed by dykes of hornblende dolerite. The hill ranges of Jamal Bariz, Kuh-i-Shah, Sawaran, and others are made up of a great thickness of fragmental volcanic rocks which rest on the Hippuritic Limestone and are probably of Deccan Trap age, dating from some part of the Danian to the beginning of the Eocene. It is probable that marine conditions continued during the accumulation of these volcanic rocks.

The Hippuritic Limestone in Seistan has yielded *Hippurites vredenburgi*, *Pironaea persica* and *Chondrodonta bösei* Vred., the horizon indicated being Upper Senonian.[1]

All stages of the Cretaceous are apparently represented in southern Persia, including the Hippuritic Limestone which is widely distributed.

In western and southwestern Persia, domes and anticlines of Cretaceous rocks cover a large aggregate area. The Neocomian, Aptian, Albian and Cenomanian are well represented, and the Turonian has been identified in a few localities. In several places the Senonian and Mæstrichtian are well developed, and the presence in Kurdistan of *Spondylus rouaulti* and a *Nautilus* comparable to *Cimonia forbesi* may indicate the presence of higher horizons of the Danian.

The Hippuritic Limestone of western Persia is exceedingly massive, very constant in lithological character, and generally devoid of fossils other than fragments of Hippuritidæ. An echinoid stage in western Persia contains the following species identical with or closely allied to fossils from Baluchistan: *Cyphosoma speciale* Cott. & Gauth., *Pyrina orientalis* Cott. & Gauth., *Hemipneustes persicus* Cott. & Gauth., *Gryphaea vesicularis* Lam., *Plicatula hirsuta* Coq., *Spondylus subserratus* Douv., *Pecten striatocostatus* Goldf., *Heteroceras hornbyense* Whiteaves. The equivalent of Douvirlle's *H. polyplocum* (Roem., and *Sphenodiscus acutodorsatus* Nœtl., all of them characteristic of the Hemipneustes Beds except the *Plicatula* which occurs in the zone of *Indoceras baluchistanense*. From about ten miles north of Khanikin come an unusual variety of *Gryphaea vesicularis*, resembling specimens from Mazar Drik in Baluchistan, and *Ostraea sollieri* Coq.; the horizon indicated is about Campanian.[2] From what has been called the Cerithium stage have been collected the following, most of them identical with or close to forms in the Cardita beaumonti beds of Baluchistan: *Omphalocyclus macropora* Lam., *Chama* cf. *callosa* Nœtl., *Cardita* (*Venericardia*) *subcomplanata* d'Arch., *C.* (*V.*) *beaumonti* d'Arch., *Turritella quadricincta* Goldf., and *Pyrgulifera* [*Hauikenia*] *striata* Douv.[3] Two other species of the Cerithium beds of Persia, *Cerithium stoddardi* Hisl. and *Morgania* [*Vicarya*; *Irania*] *fusiformis* (Hisl.), are found in the Inter-trappeans of Rajahmundry, Madras.

HIMALAYA.

Sandstone.—Where most fully developed, the Cretaceous of the Himalaya comprises the following sequence;

Flysch . . . .

Chikkim series . { Shales. . . . . .
Limestones.. . . . . . .

Giumal Sandstone . . . .

In the Spiti area of the Punjab, the Spiti Shales of Upper Jurassic age, in certain places such as Giumal (Gieumal), Kibber and Chikkim, pass up by inter-stratification into a series of hard, yellow and brown sandstones and quartzites, named after the first mentioned of these three villages. Fossils are comparatively common in the lower horizons, the most frequent being species of *Cardium* and *Pseudomonotis*. Many bivalves, most of them badly preserved, have been collected near Giumal and Chikkim while casts of *Stephanoceras* and *Perisphinctes* have been found near Kibber and Chikkim.[1]

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[1] *Rec.* XXXVIII, 223 (1909).

[2] G. E. Pilgrim. *Rec.* XXXI, 45 (1904).

[3] *Rec.* XXXVI, 183 (1907).

In the Kumaon portion of the Himalaya the Cretaceous exposures lie mostly on the Tibetan side of the boundary, in the province of Ngari Khorsum or Hundes. The range forming the watershed between the drainage of the Ganges and Sutlej in this region, and over which lead so many easy passes such as the MaRhi La (16,380 feet), the Shalshal (16,390 feet) and the Balch Dhura (17,590 feet), is composed chiefly of strata which, though apparently passing down into the Spiti Shales are of an entirely different lithological character and easily differentiated in the field.[2] In this region the Giumal Sandstone, which is well exposed between the Niti Pass and the Sutlej in Hundes, and also in the Watershed between the latter river and the Laptal drainage, is described as a grey quartz sandstone or siliceous grit weathering brown, thin-bedded and alternating with siliceous, greenish grey shales; the upper portion of this series becomes a massive, grey quartz-sandstone or quartzite. Fossils are few and ill preserved.

In Spiti the thickness of the Giumal Sandstone is given as about 300 feet but along the borders of Kumaon it has been estimated by Griesbach to be 1,200-1,500 feet. It would appear to correspond to part at least of the Red Grit series of Afghanistan.

Messrs. Heim and Gansser, in their sections of this neighbourhood, estimate the total thickness of the Giumal Sandstone at 500-700 metres (1,640—2,300 ft.), admitting at the same time that folding and faulting, the lack of a suitable map, and the absence of fossils make it uncertain whether the sequence is or is not one of continuous deposition. They describe the poorly exposed basal part of the Giumals as developing gradually from the Spiti Shales and made up of shales with glauconitic and more or less calcareous sandstones. The upper part of this series gives rise to fantastic blocks and peaks, especially north of Laptal; it forms the black rocks of the imposing peaks west of Sangcha Malla.[3] At Sangcha Talla the following section of the Giumal series is given by Heim and Gansser:—

d. Upper Giumal sandstone; massive, siliceous, greenish, with a shaly band 30 metres thick, below the middle	150-250	metres	(490-820 ft.)
c. Greenish shale, reddish to black also in the lower part, with layers of sandstone	200	,,	(455 ft.)
b. Thick-bedded, glauconitic sandstone . . .	80-100	,,	(260-330 ft.)
a. Shale with layers of glauconitic sandstone . .	50-150	,,	(165-490 ft.)

The following fossils from the Giumal Sandstone have been determined by Dr. A. Spitz[4] the ammonites have been revised by Dr. Spath:

Cardium giumalense Spitz (very common),

Ostræa sp.,

Gryphæa aff. *baylei* Guer. (found in the Upper Cretaceous of Angola),

Pecten sp.,

Tellina cf. *strigata* Goldf. (found in the European Chalk),

,, sp. (closely related to *T. beushauseni* Mull. from the Lower Senonian of Germany),

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[1] *Mem.* XXXVI, 86 (1904).

[2] *Mem.* XXIII, 79 (1891).

[3] *Denkschr. d. Schweiz. Naturf. Gesells.*, Bd. LXXIII, Abh. 1, 146 (1939).

[4] *Rec.* XLIV, 219 (1914).

Opis sp. (a large and common species, found only in casts which are comparable to *O. bicornis* Gein. from the Cenomanian of Germany),
Pseudomonotis superstes Spitz (very common; a species with a notable Jurassic facies, extraordinarily similar to *P. tenuicostata* Goepp. from the Oxfordian of Switzerland.) The "*Avicula echinata*" of Blanford and Stoliczka.[1]
Arca (?) sp. (related to *A. salbieri* Coq. from the Aptian of Spain),
Cucullæa (?) sp. (one perhaps corresponding to *C. uhligi* (see below)),
Unicardium cf. *tumidum* Briart.-Corn. (species found in the Lower Pläner of Germany),
Tapes rochebruni Zitt. (found in the Gosau beds of the Alps),
Pteria [*Avicula* (?)] aff. *sanctæ-crucis* Pict.-Camp. (species found in the Valanginian of France),
,, (*Oxytoma*) sp. (group of *P.* (*O.*) *inæquivalvis*),
Corbis (?) *montana* Spitz,
Aporrhais aff. *dupiniana* d'Orb. (species found in the Valanginian and Hauterivian of France),
Holcostephanus (*Rogersites*) cf. *atherstoni* (Sharpe) (locality uncertain; species found in the Spiti Shales, the Uitenhage of S. Africa, the Speeton Clay of England and elsewhere).
Lima aff. *arziernsis* Lor. (species found in the Valanginian of France),
Panope ["*Panopæa*"] cf. *arcuata* d'Orb. (species found in the Neocomian of France),
Hoplites (*Parahoplites*) sp. (possibly an acanthoplitid of Lower Albian age, closely related to *H.* (*P.*) *nolani* Seunes, a French form from the junction of the Aptian and Gault).
Dufrencyia (?) sp. (of Aptian age).

With regard to their age, these beds pass down into the Lochambel stage of the Spiti Shales with its rich fauna a stage which, there is good reason to believe, includes the Lower Valanginian horizon; the lower layers of the Giumal Sandstone, therefore, in all probability correspond to the uppermost Valanginian and the Hauterivian. Whilst the *Rogersites* is decidedly Neocomian, however, the other ammonites indicate a range up to the Albian or at least the basal part thereof. It has been suggested that the *Rogersites* ("*Perisphinctes astierianus*")[2] was wrongly labelled and came from the Spiti Shales below, and that the Giumal Sandstone includes scarcely more than the Aptian and Albian[3]; whilst, however, there may be some doubt as to the provenance of this ammonite, owing to an almost illegible label, there is accumulative though vague evidence from the bulk of the Giumal assemblage in favour of the view that the formation ranges down into the Lower Neocomian. Dr. Spitz remarks on the curious absence of the Trigoniae which are so characteristic of the partly coeval Uitenhage beds of South and East Africa, and which are found in the Hazara Cretaceous and the Umia group of Cutch. According to this authority, the Giumal fauna supports the lithological evidence of a shallowing of the sea after the Spiti Shales epoch and, unrelated as it is to that of the Spiti Shales, must have migrated from some other region.[4]

Chikkim series.—In the Spiti area the highest members of the Cretaceous occupy a syncline on the summit of Chikkim hill-station, behind the village, and are also found in the upper reaches of the Lingti valley above Lilang.[5] They comprise about 100 feet of light grey or white limestone which has yielded a few rare fossils, and an overlying 150 feet of soft, grey, calcareous shales which are unfossiliferous and highly folded. In the Kumaon borderland, the Chikkim Limestone is spoken of as marly here and there, but no mention is made of any overlying Chikkim Shales.

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[1] *Mem.*, V, 114 (1865); *J. A. S. B.*, XXXII, 137 (1864).

[2] According to Dr. Spath, *Holcostephanus* (*Rogersites*) *astierianus* (d'Orb.) is not itself found anywhere in India (*Pal. Ind.*, New Ser., Vol. XXV, Mem. 1, p. 11 (1939).

[3] Cotter. *Mem.*, LV, 83-84 (1933).

[4] *Rec.*, XLIV, 214 (1914).

[5] *Mem.*, XXXVI, 86 (1904).

In the Spiti area the limestone has yielded a belemnite, fragments of *Rudistes* and *Inoceramus*, and foraminifera of no stratigraphical value among which Dr. Spitz has identified :

Nodosaria sp. (recalling the groups, *soluta*, *filifromis*, *zippei* and *annulata*),
Cristellaria sp. (related to *C. lituiformis* Reuss, *C. lituola* Reuss, the Tertiary *C. rhomboidea* Czjzek, *C.* (*Robulina*) *pterodiscoidea* Gumb. and *C. kunkeri* Reuss),
Textularia sp. (one recalling *T. baudouiniana* d'Orb.),
Dentalina sp.,
Globigerina and others.

From the same bed to the east of Laptal (Lapthal, Laptel), within the Hundes boundary, come : *Cucullaea uhligi* Spitz, *Astarte* (*Eriphyla ?*) *hundesiana* Spitz and *Belemnopsis* aff. *gerardi* Opp. From its stratigraphical position above the Giumals, the Chikkim series should belong to some part of the Upper Cretaceous—a deduction confirmed by the presence of rudistids—and not necessarily to the lowest stages thereof, for, although no visible unconformity is recorded in the central and western Himalaya, it is to be observed further west in Turkistan and Khorassan.[1] Dr. Spitz seems to have misinterpreted Griesbach when he remarks that the conformity of the Chikkim series with the underlying Giumal Sandstone has been positively asserted.[2] The Chikkim series must correspond to some portion of the Hippuritic Limestone of these more westerly regions.

The Flysch.—In Johar, on the Tibetan side of the main Himalayan axis, the Cretaceous, like the Trias, undergoes a change and is largely composed of a flysch-like succession of sandstones and shales with an inconsiderable proportion of calcareous beds. One of the best exposures of the Flysch is seen on the slopes south and southeast of the Balch Dhura heights. In the Chitichun region, the Flysch is of great thickness and extent. At a distance the black rocks of the formation resemble the Spiti Shales, but are harder and devoid of ammonite concretions.

According to Heim and Gansser,[3] von Krafft mistook the topmost beds of the Flysch, which are siliceous shales and radiolarian cherts, for tuffs ; with this emendation his recorded succession becomes :

f.	Thin-bedded, red and green, siliceous shales and radiolarian cherts, passing down into	200 feet.
e.	Greenish and grey sandstones, alternating with shales, passing down into	300 ,,
d.	Hard, black, siliceous shales	30 to 40 ,,
c.	Brown-weathering, micaceous, somewhat gritty sandstone in a few thick layers with shaly partings	10 ,,
b.	Black, crumbling alum shales	200 to 300 ,,
a.	(ii) Calcareous and earthy shales, with thin bands of dense, somewhat siliceous, greenish grey limestone . . . (i) Siliceous shales of an intense terracotta colour, with a few intercalated bands of red hornstone and greenish splintery shales.	app. 100 ,,
	Giumal Sandstone	400 to 500 ,,

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[1] Griesbach. *Mem.*, XXIII, 81 (1891).

[2] *Rec.*, XLIV, 213 (1914).

[3] *Denkschr. d. Schweiz. Naturf. Gesells.* LXXIII, Abh. 1, 211 (1939).

Stage "a" is very conspicuous from a distance. Stage "b" is very similar to the Spiti Shales but differs in the occurrence therein of flaggy, brown-weathering limestones with many calcite veins, and of large ferruginous concretions devoid of ammonites; beyond some doubtful traces of belemnites in the shales and frequent plant remains in the limestones, fossils are absent. Stage "e" is very similar to the Giumal sandstones but is distinguished therefrom by its abundance of "fucoids" and indistinct plant remains; this stage passes up into "f".

The above section near Balch Dhura, is quoted more as an example of the constitution of the Flysch than as a true stratigraphical sequence. The low and undisturbed dip does not preclude overthrusting and inversion, and to such disturbance, of which the presence of exotic blocks is a witness, are probably due to the many anomalous occurrences of the various members of the Flysch. Exotic blocks are seen amid the Flysch, and some of the blocks themselves are composed of Flysch strata.

At Sangcha Malla, the Giumals appear to pass up into the Flysch, the thickness of which was found to be 1,000 metres, more than three times von Krafft's estimates. Heim and Gansser's section is as follows:—

d. Green and red siliceous sandstones and dense radiolarian horn-stones, alternating with siliceous shales	300 to 400 metres	(985—1,310 ft.)
c. Predominantly black shales or slates, with occasional layers of clay-ironstone, and limestone flags with fucoids; in the upper part brown sandstone beds passing gradually up into "d"	500 to 600 ,,	(1,640--1,970 ft.)
b. Reddish purple marly shale, and dense marly limestone folded in zigzag; a few foraminifera (Globigerinidae and Rotalidae); upper limit sharp	about 100 ,,	(330 ft.)
a. Greenish shale, with layers of sandstone, passing up into "b"	about 50 ,,	(165 ft.)

The fucoids of "c" (*Chondrites intricatus* Brongn.) are regarded as the same as those found in the Upper Cretaceous flysch of the northern Alps. The radiolarians (*Spumellaria* and *Nasellaria*) of "d" are filled and partly replaced by a bluish green glauconite. The above section is capped by serpentine and other basic igneous rocks, which are believed to have been thrust over the sedimentaries. The Flysch with its topmost bed of radiolarian chert was found by Gansser along the western shore of Raksas, the western of the two Manasarowar Lakes.

The basic igneous rocks are probably Cretaceous or post-Cretaceous in age and would correspond, therefore, to the Dras Volcanics of Kashmir. Such a conclusion supports the opinion of von Krafft who, from the complete absence of nummulites in the Flysch, and from the correlation of the sub-aerial volcanics overlying the topmost stage of the Flysch (which he mistook for tuffs) with the Eocene traps of the Indus valley, decided that the Flysch in its entirety was of Cretaceous age[1]. From the absence of true tuffs, Heim and Gansser think it probable that the flows and intrusions, which are older than the thrusting, were submarine. If so, these two writers suggest that some of the exotic blocks found in the igneous suite may represent portions of sedimentary rocks which slipped down from the coast and became embedded in the igneous flows at the bottom of a deep sea. That the sea was deep is indicated by the presence of radiolarian oozes. Heim and Gansser, in fact, deduce a long calm period towards the end of the Cretaceous, and a depth of ocean of at least 5,000 metres. (16,400 feet or some 2,730 fathoms).

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[1] *Mem.*, XXXII, 176 (1902).

Blocs exotiques.—The Balch Dhura heights are made up of masses of black, unfossiliferous, alum shales, and unfossiliferous sandstones lithologically indistinguishable from Giumal sandstone. These masses may be regarded as exotic fragments representing both the Spiti Shales and the Giumal Sandstone.[1] Sandstone blocks, all apparently of Giumal sandstone, are common throughout the exotic masses of Malla Johar, but nowhere do they dominate so much as in the Balch Dhura heights, the actual peaks of which are made up of large sandstone blocks ; the western summit, for instanee, is formed by an enormous block with particularly bold outlines. The sandstone is described as split up by innumerable small faults into angular fragments. The shaly matter in the sandstone often seems to have acted as a lubricant by means of which one block has been pushed over another. As a rule, the interstices between the blocks are filled with breccia-like matter, composed of shale and small pieces of sandstone. Not only is the Flysch recognisable in the material of some of the exotics, but the particular horizon or subdivision of the Flysch can frequently be identified—"b" and "f", for example.

The interesting discovery of exotic blocks in the Flysch to the West and W.S.W. of the Manasarowar Lakes, near Jungbwa and the Amlang La, was recently made by Herr Gansser[2].

TAL SERIES.

It has been conjectured that the Upper subdivision of the Tal series occurring in the hills below Simla and Chakrata may perhaps belong to the Lower Cretaceous and correspond to the Giumal beds. The Tal series has already been described (p. 1189).

HAZARA AND THE BORDERS OF ATTOCK AND RAWALPINDI.

In Hazara it is not always easy to draw the line between the Spiti Shales and the succeeding Giumal Sandstone, the two series attaining a combined thickness of from 200 to 300 feet. In north Hazara most of this succession belongs to the Spiti Shales facies, but in the south, out of a thickness of 300 feet, only 10-15 feet of black shaly sandstone and black shale exhibit any lithological resemblance thereto.

In north Hazara, Spiti Shales of typical appearance pass up gradually into normal Giumal sandstone, a very characteristic rock of trappoid aspect, dark olive green to dark grey in colour but weathering deeply to brown, and this in its turn changes upward rapidly but gradually into a sandy limestone dotted all over with black cherty ferruginous patches which are remnants of fossils; the latter are most crowded along the top of the rock but are almost impossible to extract. By its vivid orange colour this thin calcareous band forms a conspicuous landmark, usually from 6 to 10 feet wide, which is remarkably persistent along the strike[1]. The following cephalopods and other fossils, derived from several localities but most of them from Jabri (Jabriyan) on the Haro river, are recorded[2]:

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[1] A. von Krafft. *Mem.*, XXXII, 144 (1902).

[2] *Denkschr. d. Schweiz. Naturf. Gesells.*, Bd., LXXIII, Abh. 1, 174 (1939).

Terebratula biplicata Sow., var. *dutempleana* d'Orb.,
Pholadomya cf. *generensis* Pict. & Roux,
Turbo cf. *gresslyanus* Pict. & Roux,
Semisolarium moniliferum (Mich.) (found in the Phosphatic zone of Kohat, and the Albian of France),
Eutrephoceras (*Cymatoceras* ?) sp.,
Desmoceras latidorsatum (Mich.) (found in the Phosphatic zone of Kohat, the Utaturs of S. India, and ranging in Europe from the Lower Albian to the Lower Cenomanian),
Puzosia sp.,
Cleoniceras sp., juv.,
Douvilleiceras mammillatum (Schloth). (found also in the Phosphatic zone of Kohat),
,, aff. *monile* (Sow.),
Lyelliceras lyelli (d'Orb.)
,, *pseudolyelli* (Par. & Bon.) } ("*Ammonites mantelli* Sow." of Middlemiss),
,, *cotteri* Spath ("*Ammonites blanfordianus* Stol." of Middlemiss),
Rauliniceras (?) *versicostatum* (Mich.),
Brancoceras sp.,
Mojsisovicsia aff. *delaruei* (d'Orb.),
,, cf. *ventanillensis* (Gabb.),
Oxytropidoceras roissyanum (d'Orb.) (found in Europe, Persia, Mexico, Peru, Zululand and Angola),
,, *multifidum* (Steinm.),
,, *mirapelianum* (d'Orb.),
,, *sergipense* (White),
,, aff. *chihuahense* (Böse) (species found in Mexico),
Dipoloceras cf. *subinflatum* (Pict.),
,, aff. *bouchardianum* (d'Orb.),
,, aff. *quadratum* Spath,
Turrilitoides sp. (*hugardianus* group),
Pervinquieria sp. (cf. the Utatur *P. aequatorialis* (Kossm.)),
Prohysteroceras sp. juv.,
Hamites cf. *attenuatus* J. Sow.,
Torneutoceras spp.,
Metahamites aff. *elegans* (d'Orb.),
,, *flexuosus* (d'Orb.),
,, aff. *sablieri* (d'Orb.),
Gen. nov. (*Astiericeras* ?) sp.

From the ridge southeast of Wijjian (Bijian) has been collected a fauna which has certain peculiarities and unusual elements, including three or four species of a new genus (probably of algeritids) ; the rock also is grey instead of the usual orange, and may perhaps belong to a slightly different horizon[3] :—

Eutrephoceras (*Cymatoceras* ?) sp.,
Gen. nov. ? (Cicatritid) sp.,
Puzosia sp.,
Brancoceras sp.,
Oxytropidoceras cf. *mirapelianum* (d'Orb.),
Dipoloceras aff. *subcristatum* (Delue),
Prohysteroceras sp.,
Hamites cf. *maximus* (J. Sow.),
Metahamites sp.,
Gen. nov. (Algeritidae ?) sp.,
Belemnites sp. (larger than the usual Gault forms).

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[1] C. S. Middlemiss. *Mem.*, XXVI, 32 (1896).

[2] L. F. Spath. *Pal. Ind.*, New Ser. Vol. XV, Pt. V, p. 61 (1930) ; G. de P. Cotter. *Rec.*, LIX,406 (1926).

[3] L. F. Spath. *Pal. Ind.*, New Ser., Vol. XV, Pt. V, 61 (1930).

Dr. Spath concludes that these Gault faunas of Hazara, first recognised as such by Dr. Cotter, are, like that of Kohat, on the whole of Middle Albian age and include only a few forms of the Upper Albian (*Pervinquieria* and *Prohysteroceras*) which may be local remnants of denuded beds. The dominant genus in Hazara is *Lyelliceras*, a genus which in England is slightly younger than *Douvilleiceras*, the predominant Kohat form.

Southwards there is a rapid change in the nature of the succession which assumes a more calcareous facies. The 10 or 15 feet of black shaly sandstone and shale (Spiti Shales) are overlain by a sandstone with thin calcareous beds containing *Trigonia ventricosa* and *T. smeei;* it has been classified as part of the Giumal series but may correspond to the Lochambel stage (Lower Valanginian) of the Spiti Shales. Next come about 60 feet of alternations of this sandstone with a limestone of compacted shells, passing up into some 50 feet of the shelly limestone itself, which in turn grades up into about 150 feet of buff-coloured, thin-bedded, shaly limestone. The whole is capped by a thin ferruginous pisolite which is the lateritic base of the Eocene. In the vicinity of Shah-Allah-Ditta (Shaladitta), the Giumal series has yielded: *Trigonia ventricosa* (an Uitenhage and Umia form), a costate *Trigonia* (*T. costata* Park.) and *Gryphaea* sp.

In the Margala hill slopes fringing the Potwar plateau to the north, the thinly developed Cretaceous beds form a narrow but persistent and conspicuous band stretching almost continuously from the western end of the Darabwali spur to the Jhelum and folded in among the white Eocene limestones. Wadia records the following section in the Darabwali spur :—

	feet.
Grey and mottled, flaggy, almost lithographic limestones with badly preserved fossils	50 to 100
Bleached calcareous shales crowded with belemnite guards, and containing species of *Gryphaea*, *Corbula*, *Inoceramus* and *Trigonia*	10 to 15
Brown and purplish sandstone, quartzitic or calcareous, both types in places glauconitic, passing by transition into orange limestones; fossils consist of a few broken cephalopods	30 to 40
Grey and orange, mottled limestone, with comminuted shells . . .	10
	100 to 165

Near Khurram these beds occupy a much wider area and are appreciably thicker. The limestones show some degree of brecciation but not so much as the succeeding Nummulitic (? Ranikot) beds, into which they are described as passing gradually upwards[1]. From some Belemnite beds east of Margala, Dr. Spath has identified an Albian assemblage including forms of *Dipoloceras* similar to those found in other parts of Hazara. From the same parts Wynne records *Trigonia ventricosa*[2].

In the syntaxis between Kashmir and Hazara, Wadia records a grey, finely laminated, well jointed, unfossiliferous limestone, lying below the Subathu Limestone but separated therefrom, here and there, by pockets of coaly shale. It lies unconformably upon either the Trias, the Infra-Trias or the Panjal Volcanic series. It is 400 feet thick and belongs either to the Trias or the Cretaceous—most probably the former. It is best developed in the Kotli hills, but occurs restrictedly in the Kishenganga valley and the Kafir Khan range.

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[1] *Mem.*, LI, 257 (1928).

[2] L. F. Spath. *Pal. Ind.*, New Ser., Vol. IX, Mem. 2, 803 (1933).

Further west, in Attock, the Cretaceous is represented in the Kala Chitta range, amongst some 320 feet of strata which include the Giumal Sandstone and some portion of the Spiti Shales and correspond to a sequence of about 2,000 feet in the Samana range of Kohat. As we have seen, the lower 160-200 feet of this band are thought to belong to the Spiti Shales and have yielded ammonites of that age. The upper series of sandstones, shales and limestones varies from place to place. The most characteristic rock type is a dark purple or reddish sandstone, the cementing material of which is carbonate of lime; this sandstone is made up of thin layers of unusually coarse rounded sand grains which project from the weathered surface of the rock and look as if they had been dusted on to a sticky surface[1]. Layers of fragmentary shells and belemnites are characteristic of this rock, the shell fragments being highly ferruginous and frequently reduced to mere patches of haematite. Other types include: soft, olive-green, well-bedded sandstone, occasionally fossiliferous; earthy shale with partings of fossiliferous, calcareous clay; ochreous marly limestones, sometimes with fossiliferous layers[2]. The limestones predominate towards the top and correspond presumably to the orange-coloured limestone found in a similar position on the southern parts of Hazara. This Mesozoic band is frequently sheared and attenuated within the Kioto or the Nummulitic limestones, and is sometimes pinched out altogether. In the Kawa Gar ("Hill of Olives"), a small range north of the Kala Chitta and south of Campbellpur, the softer beds seem to have been generally sheared away and the section is probably inverted. A dark-coloured shell limestone of Cretaceous age from this unimposing range takes a fine polish and is fashioned into cups and other vessels. Articles of this nature and material have been excavated from the buried city of Taxila to the east of Hassan Abdal and are displayed in the Taxila museum.

The fossils from the Spiti Shale—Giumal Sandstone band of Attock indicate the presence of three separate horizons. The lowest, of Argovian age, and the middle, Infra-Valanginian ranging perhaps into the base of the Valanginian have already been considered (p. 1173). The highest of the three horizons is of Albian age and includes the following[3].

Exogyra arduennensis (d'Orb.) (a European form),
Pecten [*Neithea*] *attockensis* Cox,
Oxytropidoceras aff. *roissyanum* (d'Orb.),
,, cf. *acutocarinatum* (Shum.), (species found in Persia, the United States and Zululand),
Douvilleiceras sp. (4).
Dipoloceras sp., including *D. cristatum* Deluc. (4),
Belemnite fragments.

The ammonites are of Middle Albian age and may indicate immigration from the southwest where, in Persia, the Cretaceous succession including the Albian is far more continuous than it is in northwestern and northern India.

PESHAWAR DISTRICT.

The highest point of Cherat, in the district of Peshawar and west of Attock is formed by a limestone which dips very steeply beneath Palaeocene or Lower Eocene limestones probably equivalent to the Dunghan, and may, therefore, be of Cretaceous age[1]. The road from Cherat to Mir Kalan for about 2½ miles passes due east along the boundary between the older grey limestone and the Lower Eocene (? Palæocene) with its red beds. Overlain conformably by this grey limestone, which is unfossiliferous, are much plicated beds of limestone and calcareous shales, and these in turn rest on hard, light-coloured quartz-sandstone in thick beds containing numerous decomposed garnet crystals and becoming in places a garnetiferous quartzite. The quartz-sandstone or quartzite rests conformably on banded, grey, calcareous shales, some of them carbonaceous and some ferruginous, which might represent the Spiti Shales. Below them come grey foraminiferal limestones with partings of micaceous shale ; this limestone is in thick beds and contains indeterminable corals, foraminifera and small bivalves.

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[1] E. H. Pascoe. *Mem.*, XL, 384 (1920).
[2] G. de P. Cotter. *Mem.*, LV, 84 (1933).
[3] *Pal. Ind.*, New Ser., Vol. XX, Mem. 4, 30 (1934); *Ibid.*, Mem. 5, 19—21(1935).
[4] L. R. Cox. From Wynne's collections between Ghussa and Maira, and from Bhada Kas ("Juggree"); L. F. Spath. *Pal. Ind.*, New Ser., Vol. IX, Mem. 2, 803 (1933).

CHITRAL, WAKHAN AND KASHMIR.

Chitral.—In the State of Chitral, a little below Drosh, Hayden records a finely laminated, schistose limestone, full of comminuted *Orbitolina* and lying above traps which almost certainly belong to the Panjal Trap[2] ; its relationships are obscured by faulting. So far as is known, the characteristically Cretaceous genus, *Orbitolina*, though found in Afghanistan, is restricted to this corner of India. Between Partsan and Shoghor, the Cretaceous limestone sequence attains a considerable thickness. It is full of hippurites, all belonging to a new species of a genus recalling *Horiopleura* of Aquitaine[3] ; this type is accompanied by another rudistid which is probably the *Praeradiolites hedini* found by Sven Hedin in the extreme eastern end of Kashmir and by a *Nerinea* (cf. *N. coquandi* d' Orb.).

The Cretaceous limestone succession has been traced by Tipper along the edge of the river from just below Drosh Fort to the cliffs opposite Suir, where there is a more complete section. The limestones are sheared, with the consequent destruction of the larger fossils, and the superjacency with the trap is always one of unconformity ; the junction with overlying beds is generally obscured by river alluvium. *Orbitolina* occurs in the more shaly bands. One of these foraminifera from Reshun has the conical form of *O. bulgarica* Prev. ; it has been identified as such by H. Douville′ and is the same as the type collected by Sven Hedin in south-western Tibet.

The fossiliferous Cretaceous beds do not appear to continue along the strike either northeast or southwest[4]. Southeast of Buni, they are associated with Tertiary beds. From the Chamarkand Pass to the camping ground of that name, the Orbitolina limestone with some trap beds, abutting on a mass of granite, are exposed and form a continuation of that seen in Gilgit territory to the east. In calcareous shales of Cretaceous age near Partsan, realgar occurs as scattered particles[5]. The chief arsenic ore of Chitral is orpiment and is found close to a band of basic intrusive rock in calcareous shales associated with marble in several localities[6].

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[1] C. L. Griesbach. *Rec.*, XXV, 96 (1892).

[2] H. H. Hyden. *Rec.*, XLV, 279 (1915).

[3] H. Douville′. C. R. Soc. géol. France, p. 59 (1924).

[4] Gen.Rep . *Rec.*, LVI, 47 (1924).

[5] Gen. Rep. *Rec.*, LV, 13-14 (1923).

[6] *Rec.*, LXX, 344 (1935).

Burzil Gorge.—So far the Giumal facies of the Cretaceous has escaped recognition in Kashmir. In the centre of this State, on the east side of the Burzil (Dorikoon) Pass, about halfway between Gurais and Astor, some dark-coloured calcareous shales are found containing abundant Orbitolinae, often in the form of casts. One of these is referred by Professor Douvillé to *O. bulgarica*, and another to what is probably nothing more than its microspheric form, *O. discoidea*. The horizon indicated is the Upper Barremian[1].

Dras Volcanic series.—From Chechri Kadal a synclinal outlier of volcanic rocks, inverted in places, extends southeastwards across the Burzil river, through Minimarg to Dras and beyond, the outcrop widening sometimes to ten miles. The western part of this belt has been described by D. N. Wadia[2], the eastern portion was mapped by Middlemiss and has been described by De Terra[3]. For much of its length it lies between the hornblende granite of the Chhota Deosai (Chonche Barchah) valley to the northeast and the Salkhalas of the Kishenganga to the southwest ; on the latter rocks the volcanics rest unconformably. Before reaching Dras, the outcrop of these volcanics comes into contact along its southern boundary with the Upper Triassic limestones of Pindras and Matayan, against which it is in places faulted. This belt designated by De Terra the Dras Volcanics, cuts obliquely across the Great Himalaya, which here has dwindled in altitude to 18,000 feet, and in its wider parts is characterised by a complicated series of isoclinal folds and inversions. In it occurs an interesting and intimate association of marine sediments with volcanic, pyroclastic, hypabyssal and plutonic rocks. At Dras, Dr. De Terra records intrusive phases in the form of masses of gabbro, pyroxenite, peridotite and serpentine, and Wadia found dykes, sills and bosses of similar ultrabasic rocks penetrating the perfectly stratified tuffs, ash-beds and trap flows further west. The whole series has been further injected by hornblende granite, varying from thin veins to bosses several miles across. Since the volcanic rocks in Dras, some fifty miles east of the Burzil Pass, were found by Middlemiss to contain thin limestones carrying *Dictyoconoides*, *Alveolina* and Eocene gastropods, the volcanics themselves must be partly of Eocene age, unless it is assumed that strips of Eocene (? Palæocene) have been folded up with them. In any case, it seems highly probable that the granite, and perhaps some at least of the basic intrusions, are of Eocene or possibly even later age. De Terra concludes that the activity represented by the Dras Volcanics began at the end of the Cretaceous and extended into the Eocene period, this would make them co-eval with the Deccan Trap. Wadia describes the country as bleak and black, deeply dissected, uninhabited and forest-less.

The bulk of the belt consists of pyroclastic material, which takes the form of thousands of feet of purple and green, laminated, shaly ash-beds, slates, coarse, gritty and siliceous tuffs, agglomeratic slates and conglomeratic agglomerates. There are subordinate lava flows of amygdaloidal augite-andesite or basalt which, like the older Panjal trap, is chloritised and epidotised but, unlike it, is distinguished by silicified bands of bright crimson chert or jasper. At intervals in the finegrained ash-beds are nests, lenses and interbedded layers of foraminiferal or coral limestone, usually an unaltered white or grey rock varying from pockets only a few feet across to evenly bedded masses over a hundred feet thick. The agglomeratic slates and sandy beds cover a wide area and contain stray fragments of fossils and carbonised leaf impressions. They are described by Wadia as indistinguishable from similar members of the Panjal Volcanic suite, having a matrix composed chiefly of devitrified glass with a few crystalline particles. De Terra, on the other hand, finds little resemblance between the tuffaceous, unfossiliferous, purple and bright green shales of Dras, and the greyish Agglomeratic Slate of the older suite.

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[1] *Rec.*, LVIII, 349 (1925).

[2] *Rec.*, LXXII, 151-161 (1937).

[3] *Mem. Connect. Acad.*, VIII, Art. II, 54-55 (1935).

The conglomeratic agglomerate forms rudely stratified beds nearly 1,000 feet thick, of rounded and sub-angular pebbles and boulders from a few inches to two feet in diameter and composed of six or seven varieties of rock, embedded in a copious matrix which, Wadia states, is either of lava showing fluxion lines, or of bedded tuff or sandy sediment. The larger sub-angular boulders and the smaller well-rounded boulders and pebbles are made up of the following types : variously coloured felspar porphyries ; Cretaceous trap ; hornblende granite ; jasper and chert ; quartzite ; slate ; and fossiliferous limestone. This member of the succession is well exposed in the deeply scarred precipices on the south side of the Nagai valley, east of Minimarg. This agglomerate, of local and fitful occurrence, grades laterally and vertically into either agglomeratic slate or well-bedded lava flows.

The agglomerates of the Dras area, usually purplish or reddish in colour, are made up of angular fragments of metamorphic rocks such as phyllite, but more commonly of tuff, greenstone or shale. The shale of this series is micaceous and sandy, and frequently forms beds 200 feet thick in the schist complex ; in Ladakh the tuffaceous shale is described as alternating with massive Cretaceous limestones[1]. The agglomerates and tuffs are cut by dark basic dykes which appear to come from the intrusive masses.

The beds of this belt are remarkably free from the effects of severe pressure metamorphism. Wadia notes that many of the shaly beds are without cleavage, and the slates, while they possess an oblique cleavage, are free from foliation, crystalline structure or phyllitisation. The limestones, even at heights of 15,000 feet, in some cases have preserved their grain and their fossil structures. There is also no pronounced contact metamorphism. The intrusions of coarse dolerite (some now altered to epidiorites), gabbro and serpentinised pyroxenite, injected in sills or massive stocks along the outer margin of this belt of volcanic rocks, are post-Cretaceous, while the granite may be even younger than the basic intrusions. The pyroxenite, altered to dark green serpentine along an extensive system of joints and fissures, forms a very conspicuous rock-body in this tract. The dunite intrusions of Dras carry chromite ore in large visible aggregates. These basic intrusions are probably of the same age as the peridotite and dunite dykes, sills and masses, recorded in Punch and found intruding Eocene and older rocks[2].

The Dras Volcanics are the result probably of submarine eruptions which occurred during a marine submergence at the close of the Cretaceous or during the Palæocene and early Eocene. De Terra's view is that most of the detrital material was re-worked and mixed with very fine clastic sediment swept in from the crystalline highlands to the north. The first disturbance was an unimportant outflow of lava which preceded the deposition of the Senonian *Radiolites* limestone. By Middle Eocene times activity appears to have ceased, for the marls and nummulitic limestones of that age have been unaffected by the volcanic rocks.

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[1] *Mem. Connect. Acad.*, VIII, Art. II, 31 33 (1935).

[2] *Mem.*, LI, 219 (1928).

Although the Dras Volcanics would appear to cover the period of the Deccan Trap, it has been convenient to consider them here instead of in the chapter on the Deccan Trap, where they rightly belong.

Kargil.—Further southeast, on the western slope of the Kargil basin, the Upper Cretaceous Flysch has yielded a gastropod fauna of Senonian or Maestrichtian age[1], the formation has a basal conglomerate and some of the sandstones are current-bedded. The Dras Volcanics of this part of Kashmir are likewise of Deccan Trap age, commencing before the end of the Cretaceous and extending into the Eocene.

Gilgit.—In Gilgit fragments of *Orbitolina* were found by Hayden in a shale associated with a bed containing *Hippurites*. The succession here consists of a basal conglomerate, whose pebbles are composed chiefly of trap, lying upon a great mass of trap which is of typical Panjal character. Above the conglomerate comes a calcareous shale with *Orbitolina*, next an indurated sandstone, and finally an almost vertically dipping rudistid limestone; the rudistids in the latter are intensely crushed, sometimes almost completely flattened, and stand out in lumps from the weathered surface of the rock. Amongst the fossils collected from this bed, Douvillé has identified a fauna showing marked affinities with the Lower Cretaceous (Upper Barremian or Aptian) of Europe (Mésogée européenne) as follows[2] :—

Nerinea coquandi d'Orb. and *N. renauxi* d'Orb. (probably two varieties of the same species) three corals, one recalling *Rhabdophyllia gracilis* d'Orb. from the Turonian of France, another recalling *Isastraea regularis* de Form, from the Neocomian of France, and the third identical with *Eugyra neocomiensis* de Form also from the Neocomian of France. All these fossils are associated with *Orbitolina bulgarica* and its companion, *O.* cf. *discoidea*.

Wakhan.—In Wakhan, the *Perisphinctes* limestone at the head of the Kekchaki valley is overlain by massive limestone, followed by thin-bedded limestone and oolite often composed largely of echinoid spines and fragments and containing at the same time badly preserved brachiopods, oysters and calcareous algae. Similar beds were noted by Hayden in the hills opposite Ujadbai in the Taghdumbash Pamir, at the top of the Pamir Limestone, and were referred provisionally to the Cretaceous[3].

Ladakh.—In the vicinity of Leh in Ladakh, on the right bank of the Indus, some beds associated with rudistid limestones have yielded some badly preserved fossils, including the Senonian *Cicatrea cordialis* Stol.[4], together with a form comparable to *Veniella forbesiana* Stol., *Opisoma* sp. and fragmentary radiolitidae belonging perhaps to *Biradiolites*[5].

Lingzi Thang.—Further northeast, on the Lingzi Thang plains, a grey oolitic limestone with small oolitic bodies has yielded well preserved specimens of the alga, *Sphaerocodium*. From the top of a rudistid limestone in the same region come *Trochosmilia* sp., the bryozoon *Reptomulticava* cf. *irregularis* d'Orb., *Radiolites indica* (Stol.) (a form belonging possibly to the group *Radiolites radiosus* d'Orb.), *Radiolites* cf. *peroni* (Choff.), *Radiolites* (*Durania*) cf. *arnaudi* (Choff.), and

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[1] H. De Terra. *Mem. Connect. Acad.*, VIII, Art. II, 39 (1935).

[2] *Rec.*, LVIII, 350 (1925).

[3] *Rec.*, XLV, 309 (1915).

[4] Parona calls it "*Cicatrea* (*Roudaireia*) *cordialis* Stol".

[5] C. F. Parona. *R. Acc. Lincei.* Ser. 5, Vol. XXVI, 53-57 (1917).

Gyropleura cenomanensis (d'Orb.); this fauna is presumably Turonian. Another limestone shows miliolids (*Lacazina*, *Cuneolina*, etc.) and dacycladaceous plants (*Neomeris*). Yet another limestone on these plains is characterised by crinoids and fragments of echinoderms, and by *Exogyra ostracina* (Lam.), *Pecten* sp., *Hemiaster* sp., and *Cellepora* sp.

From " Aksaitchan ", a locality in the eastern parts of the Lingzi Thang plains Sven Hedin's expedition brought back specimens determined by H. Douvillé as *Orbitolina conulus* and *Choffatella* sp. and assigned to the Barremian; a specimen to which was given the name of *Praeradiolites hedini* Douv. indicates the presence also of either the Albian or the Cenomanian[1]. South of this locality Parona records a fauna containing *Pervinquieria inflata* (Sow.) from latitude 34°20′; longitude 79°. From the Prega plain the De Filippi expedition has collected the following, determined by Stephanini[2]:

Heterodiadema libycum Des., var. *asiatica* Stef. (species found in the Cenomanian of the whole of the Tethys area),
Diplopodia sp.,
Orthopsis sp.,
Micropedina olisiponensis (Forb.) (found in the Cenomanian of Portugal, Algeria and Egypt),
Pygopyrina pusilla Stef.,
Holaster marinellii Stef.,
Hemiaster orbignyanus Des., var. *minor* Stef. (*forma typica* found in the Cenomanian of Egypt),
,, *stoliczkai* Stef.,
,, *gabrielis* Cott. Per. Gauth. (found in the Cenomanian of Algeria and Palestine),
,, *ameliae* Cott. Per. Gauth. (found in the Cenomanian of Algeria and Persia),
Linthia dainellii Stef.

Chisil Pass.—From a limestone occurring in the valley which extends westward from the Chisil pass have been collected:

Chonia perforata Seg.,
Exogyra columba (Lam.) (probably equivalent to the Utatur *E. suborbiculata* (Lam) Stol.),
,, *delettrei* Coq.?,
,, *africana* Lam.,
Plicatula auressensis Coq.?.
Pecten verdachellensis Forb. (an Utatur species),
,, cf. *puzosianus* Math.,
Modiola typica Forb. (found in the Trichinopoly stage, and in the Gosau Turonian),
Trigonoarca (?) *thevestensis* Coq.,
Trigonoarca cf. *moutonia* d'Orb.,
Anisocardia aquilina (Coq.),
Pholadomya carantoniana d'Orb.,
,, cf. *archiaciana* d'Orb.,
Liopistha [*Psilomya*] cf. *molli* Coq.,
,, ,, *ligeriensis* d'Orb.,
Neokentroceras gracillimum (Kossam.) ("*Schloenbachia gracillima* Kossam."; an Utatur form),
Pervinquieria inflata (Sow.) (An Utatur species; Stephanini distinguishes "*Schloenbachia inflata* (Sow.)" and "*Mortoniceras inflatum* (Sow. in Pervinq),"
Acanthoceras jimboi Perv.,
,, *haugi* Perv.,
Vascoceras polymorphum Perv.?

The same rock in a neighbouring locality has yielded in addition: *Exogyra costata* Say. (an Utatur species), *Inoceramus multiplicatus* Stol. (a Trichinopoly species), *Pinna* cf. *complanata* Stol. (also a Trichinopoly species), *Astarte* (*Eriphyla*) *lenticularis* (Goldf.) (also a Trichinopoly species), and *Cuspidaria* [*Neaera*] cf. *detecta* (Stol.) (an Utatur species). This fauna shows a great prevalence of Cenomanian forms. Its chief interest lies in its close affinity with the Utatur of southern

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[1] *C. R. Soc. géol. France*, p. 59, (1924).

[2] Spedizione italiana de Filippi nell' Himalaia, Caracorum e Turkestan cinese (1913-14) Ser. II, Vol. VI.

India, with which it has six identical or closely allied species in common ; three of its lamellibranchs and one comparable species are found in the Trichinopoly stage.

Karakoram Pass.—From a locality near the Karakoram Pass, an Upper Senonian to Danian assemblage has been obtained, including:

Doryderma sp.
Caryophyllia arcotensis Stol. (An Ariyalur and Niniyur species).,
Holocoenia indica Stol. (a Niniyur species),
Thamnastraea cf. *brevipes* Stol. (species found in the Niniyur Stage),
Megathyris [*Argiope*] sp.,
Rhynchonella mutua Stol. (An Utatur species),
„ *ariyalurensis* Stol. (An Ariyalur species),
Terebratula (*Rectithyris*) *subdepressa* Stol. (An Ariyalur species),
Magellania [*Waldheimia*] sp.,
Alectryonia pectinata (Lam.) (A world-wide species found in the Ariyalur stage of S. India as well as in the Hemipneustes Beds of Baluchistan),
„ *arcotensis* Stol. (An Ariyalur species).
Cardium (*Trachycardium*) *exulans* Stol. (An Ariyalur species),
Pholadomya cf. *indica* Noetl. (A species found in the Des valley, Baluchistan).

Again we find a very close relationship to southern India, this time to the Ariyalur and Niniyur stages, the Karakoram rock containing six Ariyalur species including a *Caryophyllia* found in both the Ariyalur and Niniyur groups, two other Niniyur corals, and an Utatur brachiopod. The same fauna has been collected from the "Ammonite Valley" of the same neighbourhood which in addition yielded the Cenomanian coral, *Eupsammia varians* Stol. found in the Utatur stage of southern India. From this region Stephanini also identifies : *Typocidaris* (?) sp., *Pseudocidaris de Filippii* Stef. and *Polycyphus rimuensis* Stef[1].

SOUTHERN TIBET.

Kampa Dzong region.—The contrast between the Cretaceous and Jurassic of southern Tibet is striking in the extreme, the former being mainly calcareous, with a large and varied fauna and of very limited distribution, while the older is a sparsely fossiliferous system of enormous extent, made up chiefly of arenaceous and argillaceous beds.

From Kampa Dzong to Tuna, there extends a narrow but widening strip of Cretaceous, Palæocene and Eocene rocks, to the whole of which the term Kampa system has been applied by Sir Henry Hayden[2]. These rocks occupy a series of approximately E.-W., more or less faulted folds, and are well exposed in a conspicuous range of hills standing out in the middle of the plain in the neighbourhood of Kampa Dzong ; good sections are also seen in the hills near Tüna. The system has been subdivided as follows :

16. Dzongbuk shales	Eocene.
15. Dzongbuk limestone	
14. Spondylus shales	Palæocene.
13. Operculina limestone	
12. Gastropod limestone	
11. Ferruginous sandstone	

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[1] Spedizione italiana de Filippi nell' Himalaia, Caracorum e Turkestan cinese (1913-14) Ser II, Vol. VI.

[2] *Mem.*, XXXVI, 161 (1907).

10.	Grey limestone with indeterminable echinoids and brachiopods	Danian.
	Sandstone, apparently unfossiliferous	
	Lithothamnium limestones	
9.	Red sandy limestone	
	Grey limestone	
8.	Brown limestone, with *Omphalocyclus*	
7.	Thin-bedded limestone	
6.	Third Scarp limestone	Upper Senonian (Campanian).
	Shaly limestone	
5.	Second Scarp limestone	Lower Senonian (Emscherian).
	Shales with thin bands of limestone	
4.	First Scarp limestone	
3.	Hemiaster shales	Turonian.
2.	Kampa shales	Upper Cenomanian.
1.	Giri limestone	? Lower Cretaceous.

The oldest member, the Giri limestone, is hard, compact, thin-bedded and unfossiliferous, and overlies the Spiti Shales.

The Kampa shales comprise brown shaly limestone with brown and black needle shales ; through the latter run narrow bands of very hard, splintery concretionary limestone. From these beds Prof. Douvillé has identified the following[1]:

Acanthoceras newboldi Kossm. (An Utatur species).
,, ("*Mantelliceras*") *laticlavum* Sharpe (variety found in the Utatur stage).
,, ,, *discoidale* Kossm. (An Utatur species).
Turrilites costatus Lam. (An Utatur species).
,, *wiestii* Sharpe,
,, *desnoyersi* d'Orb.

The material of the fossils, which are not well preserved, is often replaced to a large extent by crystalline silica, usually in the form of bipyramidal crystals of colourless or yellow quartz. The fauna is obviously Cenomanian.

The following 250 feet of pale grey shale form one of the most conspicuous features of the Kampa-Tatsang range. Fossils are rare, but a few well preserved echinoids and some lamellibranchs have been collected from the base. The lamellibranchs occur chiefly in two narrow calcareous bands composed almost entirely of specimens of a small *Gryphaea* : the only other fossil found in any quantity in this bed is an *Inoceramus*. From these beds, known as the Hemiaster shales come :

Hemiaster cf. *grossouvrei* Gauth.,
,, cf. *cenomanensis* Cott.,
Inoceramus sp.,
Plicatula(?) *radiola* Lam.,
Gryphaea vesiculosa Sow.

For this fauna Douville' suggests a Turonian age, but the indications are not definite. A narrow calcareous band in similar shales on the western flank of the Kampa ridge has yielded numerous badly preserved specimens of *Lithophaguś* (*Lithodomus*).

In the remainder of the section, which consists chiefly of limestone, the southern edge of the outcrop everywhere forms a well marked scarp in which three prominent bands are usually noticeable, separated from one another by softer shaly beds ; one of the most complete sections is to be seen about seven miles east of Kampa Dzong in the Kampa-Tatsang range. The First Scarp limestone is a dark splintery rock with no determinable fossils ; the overlying shales with thin bands of limestone are also practically unfossiliferous, having yielded only a few fragments of lamellibranchs including those of a small *Gryphaea*. Both limestone and shales may be referred provisionally to the Lower Senonian.

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[1] *Pal. Ind.*, New Ser., Vol. V, Mem. 3, 4-46 (1916).

Above the last-mentioned shale, fossils begin to appear in the base of the Second Scarp limestone, and a few feet higher up numbers of small *Orbitoides* make their appearance; these gradually become more and more numerous and are an almost constant feature of the limestone bands up to the base of the Ferruginous Sandstone (No. 11). This part of Tibet, in fact, is described as affording an almost unique opportunity for the study of the evolution of *Orbitoides* nearly from its earliest appearance up to the end of the Danian epoch. The rudistids form another characteristic element and make their first appearance towards the upper part of the Second Scarp limestone; species of *Bournonia* or *Biradiolites* range from this horizon through the overlying shales into the base of the Third Scarp limestone. The top of the latter is characterised by a large *Actaeonella* and numerous specimens of the large *Gryphaea vesicularis*, associated with extremely abundant *Orbitoides*. According to Douvillé, the Second and Third Scarp limestones with the intervening shales correspond to the Campanian or Upper Senonian, which is here characterised by the appearance of *Orbitoides*; the uppermost horizon of the Third Scarp limestone has yielded abundant examples of *Orbitoides media*, a species especially characteristic of the Pyrenees Dordonian (Maestrichtian). From the two limestones and intervening shales come:

Orbitoides vredenburgi Douv. (abundant in the Second Scarp limestone; closely allied to *O. tissoti* Schlumb. from the basal Campanian of Tunis; the "*O. apiculata* Schlumb." of Vredenburg),

,, *media* d'Arch. (Third Scrap limestone) [1],

Actaeonella crassa Duj. (Third Scarp limestone; found in the Turonian and Senonian of France),

Radiolites (*Bournonia* or *Biradiolites*) *haydeni* Douv. (Third Scarp limestone; found also in the Campanian of S. W. Tibet[2]),

,, ,, ,, *tibetica* Douv. (Third Scrap limestone and subjacent shales; found also in the Campanian of S. W. Tibet (*Ibid.*)),

Inoceramus (*Endocostea*) *haydeni* Douv. (exact horizon unknown but probably the Third Scarp limestone),

Lima sp. (found in the *Actaeonella* bed),

Gryphaea vesicularis (Lam.).

Above the Third Scarp limestone are some soft, thin-bedded limestones which constitute stage (7) and contain casts of echinoids including *Holectypus*, *Echinanthus* and *Pyrina*, and of lamellibranchs, principally the so-called *Pecten* [*Neithea*] *quadricostatus* Sow., thought by some to be specifically indistinguishable from *P. quinquecostatus* Sow[3]. These are overlain by a band of brown limestone containing *Hemipneustes* sp., closely allied to *H. depressus* Noetl. and to *H. persicus* Cott. & Gauth., *Pecten quadricostatus* Sow., fragments of small brachiopods and large numbers of foraminifera, the chief forms being *Orbitoides tenuistriata* Vred. (probably a variety of *O. media* d'Arch.) and *Omphalocyclus macropora* (Lam.)[4] this is Hayden's stage (8). Stage (9) has well marked and easily recognisable characters and has been divided into three sub-stages, a lower thin-bedded, grey limestone, a middle thin-bedded, reddish and arenaceous limestone, and an upper limestone containing immense numbers of calcareous algae. The last is only a few inches thick ; it and, apparently, certain other bands in the stage are composed almost entirely of large spheroidal nullipores belonging probably to the genus, *Lithothamnium.* This uppermost Lithothamnium limestone is also characterised by a species of *Lithophagus* apparently identical with *L.* (*Lithodomus*) *deshayesi* Dixon from the Calcaire Grossier of the Paris Basin and occurring in considerable numbers, by *Lepidorbitoides* aff. *socialis* (Leym.) ("*Orbitoides* aff. *minor* Schlumb."), *Omphalocyclus macropora* (Lam.), *Echinobrissus* sp., *Echinanthus* sp. (closely related to an undescribed form in the *Indoceras* zone of Mazar Drik, Baluchistan), *Hemipneustes tibeticus* Douv., a doubtful *Vologesia*, *Caprina* sp. and other lamellibranchs, and the bryozoan, *Cyclolites regularis* Leym. The reddish sandy limestone contains *Pyrina* cf. *gigantea* Noetl., *Hemipneustes tibeticus*, *Pecten quadricostatus* Sow., *Plicatula hirsuta* Coq., *Nerinea ganesha* Noetl., and the final representatives of the genera *Plagioptychus* and *Kingena* in the species *P. tibeticus* Douv. and *K. heberti* d' Orb. which are apparently found also in the grey limestone below ; *P. tibeticus* has also been collected in S. W. Tibet. Resting on the Lithothamnium limestone, stage (10) comprises an unfossiliferous sandstone and a grey limestone with a few echinoids and traces of brachiopods. Stages (7), (8), (9) and (10) are assignable to what we are calling the Danian, and represent a continuation of the beds in Persia and Baluchistan with *Omphalocyclus macropora.* From one of the Danian limestones of Kampa Dzong comes the alga *Cymopolia tibetica* Mor.

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[1] "*Orbitoides tenuistriata* Vred." is said to come from the Third Scarp limestone, but Douvillé suggests that this may be a mistake (*Pal. Ind.*, New Ser., Vol. V, Mem. 3, 33 (1916).

[2] *C. R. Soc. géol. France* p. 59 (1924).

[3] F. Stoliczka. See *Pal. Ind.*, Ser. VI, Vol. III, 438 (1870-71). Noetling's specimen was redetermined as *P. faujasi* (Pict. & Camp.).

[4] E. W. Vredenburg. *Rec.*, XXXVI, 187 (1907).

The succession from the Third Scarp limestone to stage (10) inclusive has been called by Hayden the " Tüna limestone ", since it is well seen near that town[1]. From the base of the Second Scarp limestone to the top of the Tüna limestone the aggregate thickness is estimated by Vredenburg to be nearly 600 feet of strata which correspond to the *Hemipneustes* and *Cardita subcomplanata* beds (Olive Shales) of Baluchistan.

The top of the Tüna limestone is invariably overlain by about 200 feet of coarse ferruginous sandstone. This and the three succeeding stages (12), (13) and (14) were included by Douvillé in the Danian, but the allocation has been questioned by Vredenburg and Cotter[2], whose reasons for assigning stages (12), (13) and (14) to the Eocene—or rather to the Palæocene—as Hayden originally did, will be discussed under that heading. There remain the unfossiliferous Ferruginous sandstones. This might represent the top of the Danian but it seems more logical to regard it, as Hayden appears to have done, as the lateritic local base of the tertiary. It and the rest of the Kampa system are described in the sequel.

Some of the calc-schists mapped as Jurassic around Gyantse may include in folded patches of Cretaceous. Here, as well as along the shores of the Yamdrok Tso, there are great intrusions of basic igneous rock among the younger Mesozoic beds.

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[1] *Mem.*, XXXVI, 165 (1907).

[2] *Rec.*, LIX, 410-418 (1926).

CENTRAL TIBET.

The Orbitolina Limestone of Gilgit and Chitral was found again by Hayden in the region of the Great Lakes of Tibet, some two hundred miles W. N. W. of Lhassa; from Kyatsok, at the northwestern end of the Kya-ring Tso, the best preserved fossils are: megalospheric and microspheric forms of *Orbitolina tibetica* Cotter, a species closely resembling *O. shikokuensis* Yabe & Hanz. and an East African species regarded as *O. bulgarica* Prev[1]. The age of the beds might be Hauterivian or Barremian.

MOUNT EVEREST AREA.

To the north of Mount Everest, east of the region just described, the Kampa system is developed principally in two overfolded and in places recumbent isosynclines, with a general dip to the north. The most complete section, including the combined Palæocene, Eocene and Cretaceous, is seen in the more northerly syncline which, with both limbs dipping north at from 20° to 40° but affected by minor corrugations, occupies the picturesque and sacred ridge of Tsipri; eastward the dip steepens but in the Lo Chu, northeast of Shekar, the fold flattens again to a very recumbent isocline.[2] The general section, including the Tertiary beds, is as follows:

Eocene and Palæocene.	Thick-bedded grey limestones with abundant *Alveolina* and *Operculina*, alternating with white, very fine-grained, unfossiliferous limestones, some of them massive and some thin-bedded. These beds form a bold scarp and probably represent a Tertiary section ranging from the Operculina limestone (stage 13) to the Dzongbuk limestone.
Palæocene and Cretaceous.	A minor scarp composed of limestones in regular beds of medium thickness, at about the middle of which occurs the Ferruginous sandstone; these beds appear to correspond to the Gastropod limestone (12), the Ferruginous sandstone (11) and stage (10), in a general way.
Cretaceous	Grey flaggy limestones, roughly equivalent to stage (9) or parts thereof. Brown argillaceous limestone in thin regular beds, forming the low scarp rising from the plain, correlating presumably with stage (8). A great thickness of unfossiliferous, grey, calcareous shales, exposed at the eastern end of the ridge; correlating perhaps with some or all of the stages (3) to (7). Black and brown splintery shales with large septarian nodules, found at the eastern end of the ridge. These have much in common with the Kampa shales. Grey limestone (? Giri limestone). Massive "Wall quartzite", wanting in places. These beds are seen in the northern limb of the fold.

At Menkhap Me and the Lungchen La in the Yaola syncline, which is a structural continuation westwards of the Tsipri fold, there is a passage downwards from the Cretaceous into the Jurassic shales, through shaly limestones. Around Shekar in the Tsipri syncline the beds are sheared and shattered to some extent and veined with calcite; in the Lo Chu shaly partings between the limestones have been sericitised.

Along the more southerly of the two synclines the Phung Chu, the main river of the region, has excavated its valley, and in the westerly continuation of the fold the Men Chu, a feeder of the Phung Chu, has done the same. The dips in the southern syncline are steeper than they are in the northern, and from Tingri eastwards the southern limb is comparatively regular, the " Wall quartzite " standing up conspicuously along the valley about 120 feet thick ; the northern limb is for a few miles affected by a strike fault.

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[1] G. de P. Cotter. *Rec.*, LXI, 354 (1928).

[2] A. M. Heron. *Rec.*, LIV, 227 (1922).

Between the two main synclines described and Mount Everest, in the Pharuk district, there are several minor synclinal exposures of Cretaceous rocks of great irregularity and complexity. In one of these outcrops, between Namda and Tashidzom, the " Wall quartzite " and the basal Cretaceous limestones are repeated again and again by sharp folds and faults of small throw and characterised by calcite-veining and brecciation.

SOUTHWESTERN TIBET.

North of the Manasarowar Lakes, around Darchen in the Kailas region, Gansser records the presence of what appears to be a metamorphic facies of the Flysch in the form of reddish sandstones, passing to red shales or slates, with chert which has a radiolarite aspect.[1] Among the rocks are masses of serpentine enclosing blocks of massive dolomite, the whole recalling the Flysch of the Amlang La and Kiogarh. Northwards the beds pass into grey-brown phyllites, fine calcareous schists and brown sandy slates which also contain serpentine rocks, and a 60-foot band of limestone ; the serpentine gradually disappears further north.

From a locality south of Jiachen (" Dschiatschan " ; 31°20′ ; 81°30′), sixty or seventy miles north of the Manasarowar Lakes, the expedition of Sven Hedin brought back specimens recognised by H. Douvillé as *Orbitolina bulgarica* Prev. and *O.* cf. *discoidea* and signifying an Upper Barremian age.[2] At a considerable distance further east, at Pati Bo, Gobrang, southeast of Lhung Nak (31°50′ ; about 86°) this Orbitolina limestone was again found and yielded the same two fossils ; here the Albian is also represented by *Orbitolina subconcava.*

BURMA.

Arakan Yoma.—The occurrence of Cretaceous rocks on the east side of the Bay of Bengal was first established in 1872 by the discovery near Ma-i (Theobald's " Mai-i ") in the northern part of the Sandoway district, of a specimen of the Upper Albian (Vraconnian) ammonite then called " *Schoenbachia inflata* (Sow.) ",[3] but now known as *Pervinquieria inflata* (Sow.), evidently weathered out from a deposit of shale. The heterogeneous assemblage which Theobald included in his " Axial Group " includes shales which have yielded some moderately well preserved *Cardita* which Mr. Tipper has identified as *Cardita* (*Venericardia*) *beaumonti* d'Arch. and some poorly preserved gastropods including *Turritella.*[4] In addition rocks mapped doubtfully as Cretaceous by Theobald extend down the western flank of the Arakan Yoma from Kyaukphyu for some 95 miles to a point on the coast about thirty-five miles south of Sandoway. These Cretaceous strata are composed chiefly of shales with one or two intercalations of argillaceous limestone, in places reduced to flat concretions, and a greyish earthy sandstone which is sometimes pisolitic.

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[1] *Denkschr. d. Schweiz. Naturf. Gesells.*, Bd. LXXIII, Abh. 1, 187 (1939).

[2] *C. R. Soc. géol. France* p. 59. (1924).

[3] *Mem.*, X, 311 (1873).

[4] *Rec.*, XXXV, 119 (1907).

Our geological knowledge of the Arakan Yoma of Burma is very incomplete. Its southerly end was cursorily surveyed during the late' 60's of the last century by Theobald who differentiated a central core, whose outcrop is mapped as terminating southwards in a point about sixteen miles west of the Irrawaddy at Prome, under the name of " Axial Group ". The term was originally proposed for the whole of the more altered rocks which occupy the main Arakan range but was subsequently restricted to the older portion of the succession at that time considered to be Triassic in age, the term Negrais being applied to the younger portion. The question of the age of these beds has been recently dealt with in some detail by Dr. Cotter[1] and Mr. Clegg.[2] By Theobald the Axials were subdivided as follows :

		feet.
" Upper "	(*e*) Sandstones, etc.	147
	(*d*) Shales and sandstones	2,197
	(*c*) Freckled grits, etc.	1,365
	(*b*) " Halobia limestone ", shales, etc..	33
	(*a*) Cardita shales	110
" Lower "	Shales and sandstone	minimum 300
	Minimum	4,152

As, however, it is in all probability from the Cardita shales (*a*) that the specimens of *Cardita beaumonti* were obtained, the rest of the sequence is either post-Maestrichtian and probably Tertiary, or is not a true stratigraphical succession. The " Halobia limestone " was so-called because it was supposed to have yielded a Triassic species of *Halobia.* If this had been the case, the " Halobia limestone " could not have been younger than the Cardita shales, but Mr. Clegg has shown good grounds for suspecting that the specimen identified as *Halobia* was mislabelled and came from Karenni and not from the Arakan Yoma.

Most probably the Axial group is a composite one, and it is possible that the bulk of it belongs to the Tertiary and is a somewhat metamorphosed facies of the earlier part of that system. Whatever the beds are collectively, they have been mapped by Theobald with an outcrop probably under 20 miles wide and a maximum thickness of rather less than 6,000 feet, occupying for a long distance the crest of the range, but lying for the most part to the east thereof, and terminating southwards in the Than-ni stream. Its western boundary has not been surveyed in detail but probably coincides more or less with the Ga-mon valley, a tributary of the Mai-i; here it is in contact partly with the Negrais beds into which it merges, and partly with an intervening strip of Nummulitic rocks against which it is probably faulted. The dip is mostly high and the folding often reversed and accompanied by contortion. The beds have undergone a certain amount of alteration but, except in the immediate neighbourhood of the larger serpentine intrusions, not to the extent of the production of slates and quartzites. Small veins of quartz are numerous in the rocks.

The so-called lower divisions of Theobald's group consists of at least 300 feet of dark and greenish, flaggy shales, succeeded by a stage of shale and sandstone, capped by dark thin-bedded shales with carbonaceous markings. The Cardita shales (*a*) belong definitely to the Cretaceous. Stage (*b*) is composed partly of a rubbly limestone and partly of shale and conglomerate. Stage (*c*) is a very characteristic one, comprising white freckled grits and conglomerates, mostly of no great coarseness, and cream-coloured argillaceous sandstones which often have a sub-porcellanous or lithographic aspect. The coarser conglomerates are composed mainly of sub-schistose argillaceous rocks, but small white quartz pebbles abound in the finer varieties. Some of the sandstones are hard and contain strings of quartz pebbles, sometimes irregularly disseminated, sometimes localised in bands. From Theobald's description, certain angular fragments in one of the sandstones, some of them nearly a foot in diameter, are of the same origin as the tectonic erratics found by Hayden further north. Stages (*d*) and (*e*) call for little comment; shales apparently predominate in the lower portions but in the higher horizons the balance between shale and sandstone is more even, the uppermost 150 feet consisting of sandstone only, some of it gritty or conglomeratic.

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[1] *Mem.*, LXXII, 21-37 (1938).

[2] *Ibid.*, 175-195 (1938).

Speaking of the Axials west of Mindon in Thayetmyo, Mr. H. S. Bion says that the group, though separable as a lithological sequence marking special conditions of deposition, passes up insensibly into the Numumlitics.[1] Here the Axials are characterised throughout by grits; ashes and shales which are often porcellanous. The grits, though rarely attaining, the character of conglomerate, are often coarse and occur throughout the group. Most of them, according to Bion, are largely made up of ash, and a striking feature is the presence of pellets of clay derived from some pre-existing clay bed. A common type in these beds is a dark hardened clay which shivers into small fragments under the hammer. The sandstones are described as weathering into spheroids in exactly the same way as basalt. Bion's opinion was that the beds could not have been deposited far from their source of origin. From the beds he collected the cast of a *Schizaster*, a doubtful *Cardita*, some small Corbulae, some gastropod casts, a doubtful ammonite, and *Lithothamnium*. In the Pazon Chaung he records the following section:

4. White sandstone;
3. Clays with fossils (small Corbulae), gastropod casts, the doubtful *Cardita*, and a small doubtful ammonite;
2. Limestone and calcareous conglomerate with *Lithothamnium*;
1. Massive conglomerates, grits and sandstones.

Farther north, in the Minbu district, the Axial group is broadly represented by the Chin Shales. To what extent the two terms are synonymous further work will decide, but the Chin Shales, as defined by Noetling, include at least 227 feet probably 500 feet, of beds which Theobald grouped with the Nummulitic. Marching from the Irrawaddy, Hayden found that the Chin Shales began about one-and-a-half miles west of Shauktaung continued without interruption to Won, and were well exposed in the Man Chaung, one-and-a-quarter miles west of this village[2]. Broken-backed anticlines are very common in this area, the rocks being greatly crushed, contorted, overfolded and faulted. The sequence consists of an immense thickness of green and purple shales containing enormous quantities of vein quartz. In the degree of alteration and disturbance they have undergone the Chin Shales contrast with the Tertiary rocks along their eastern border.

In the vicinity of a band of quartzite interbedded with the shales, Hayden found numerous strings of quartzite pebbles and boulders, from blocks weighing several tons to fragments of an inch or so across, lying along the cleavage planes of the shales with their long axes parallel to the cleavage ; they are regarded as erratics derived from the quartzite band by the intensive shearing and thrusting which have broken up the latter.

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[1] E. L. G. Clegg, *Mem.*, 72, 185-186 (1938).

[2] *Rec.*, XXIX, 75 (1896).

As in the Axials of the south, serpentine intrusions are found in large masses in the shales, and in the Man Chaung west of Won great masses and dykes of intrusive grey dolerite are to be seen.

The increase in metamorphism shown by the Axials when followed northwards is most marked in the Pakokku district and the Pakokku Chin Hills. The rocks were named provisionally the Kanpetlet schists by Dr. Cotter who, however, subsequently came to the conclusion that they were but a more highly altered facies of the Axial beds. One of the commonest types in this latitude is a talc-schist containing iron oxide which weathers in bright red hues[1]. The rest of the succession here consists mainly of mica schists, chlorite schists, quartzites, satin shales and blue shaly schists, with vein quartz and steatite veins. These schists stretch westwards to the top of Mount Victoria and the unnamed peak to the west. Eastwards the Kanpetlet schists are gradually replaced by the more normal type of Axial beds.

Still further north, around Akral, a village northeast of the town of Manipur the only rocks differentiated from the Disangs by Mr. R. D. Oldham, who doubtfully equated the latter with the Axials, were tentatively grouped as Cretaceous and contain a limestone identical in every way with the Ma-i limestone of Sandoway but contain no fossils[2]. The writer found no trace of this limestone further north in the latitude of Sarameti peak (12,557 feet). Here the monotonous flysch succession is interrupted by a conglomerate, well seen to the east of Chimi village and containing pebbles of serpentine. The beds on the east side of the conglomerate are somewhat more highly metamorphosed and have a more foliated habit and a harder texture than the Disang beds to the west and may perhaps belong to an older series[3]. Like the Disangs, the Makwari beds, as the more easterly series has been called, consist mainly of argillaceous deposits with occasional arenaceous bands, the only difference being a greater degree of metamorphism, most of the beds having taken on a foliated habit and a harder texture. These rocks, especially along their boundary with the Disangs, are characterised by serpentine intrusions which are probably of Upper Cretaceous age (see page 1325).

Fossiliferous Cretaceous in Pakokku.—In the Pakokku district, from a loose fossiliferous boulder lying at the junction of the Kyauksit and Kyaw Chaungs, Cotter obtained fossils provisionally identified as *Nerinea* sp. and *Trochalia* sp., and indicating an Upper Cretaceous age[4]. In the hills further west, two miles northeast of the village of Wabotaung, species of *Exogyra* and *Orbitoides* were collected from coarse buff sandstones which probably occur as outliers in the Axials.

Further north, at Yesbin, from an horizon about 180 feet below a bed containing Ranikot (Palæocene) fossils, B. B. Gupta has collected and identified a few badly preserved fossils of Upper Cretaceous aspect ; these are : *Orbitoides spiculata* Schlumb., *Cinularia* sp., *Roudairia* sp., *Pyrula* sp., *Dosinia* sp., *Natica* sp. and a

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[1] *Mem.*, 72, 31 (1938).

[2] *Mem.*, XIX, 223 (1883).

[3] E. H. Pascoe. *Rec.*, XLII, 261 (1912).

[4] *Mem.*, 72, 32 (1938).

Cyprimeria possibly identical with *C. analoga* Forb. of the Cretaceous of southern India. This fauna, which has resemblances to that of the Hemispneustes Beds of Baluchistan, occurs in the basal beds of the Laungshe Shales, which will be more fully dealt with under the heading of Palæocene.

Ramri Island.—From the Bay of Zinchaung in Ramri Island, which forms part of the Kyaukphyu district, a Cretaceous ammonite has been collected by Mr. H. J. Davies and identified by Dr. Spath as a species of *Acanthoceras* (*Mammites*)very close to a form from the uppermost Utatur described as "*Ammonities conciliatus* Stol." *Acanthoceras conciliatum* (Stol.), which in turn is a near relative of *Mammites nodosoides* (Schloth.), a Lower Turonian species[1], the suture line of the Burmese specimen also has resemblances to that of *Pseudoceras footeanum* (Stol.) from the Middle Utatur of southern India. The age of these Ramri rocks, therefore, is Turonian, and probably Lower Turonian. The doubtful occurrence of a species of *Placenticeras* of the group *Guadaloupae*, from the same island (precise locality not recorded) may indicate the presence of younger portions of the Turonian corresponding to the Trichinopoly stage[2]. This ammonite may prove to be identical with or closely related to the Bagh species *Placenticeras mintoi* Vred. or *P. tamulicum* Blanf., from the Trichinopoly stage of southern India ; a similar form has been described from beds immediately overlying the Wadhwan Sandstones of Kathiawar.

ANDAMAN AND NICOBAR ISLANDS.

The rocks of the Andaman Islands are a continuation of those of the Arakan Yoma. The structure is that of a disturbed anticline thrust or overfolded towards the west. In spite of this, both sub-aerial and submarine slopes are much steeper on the eastern than on the western side. This unexpected feature is thought to be due to the presence to the eastward of a large normal fault, in addition to the thrust-plane further west ; on the line of this fault lie the Recent volcanoes of Barren and Narcondam[3]. The Miocene beds are only slightly disturbed, so that the bulk of the earth movement must have ceased before their deposition.

Among the pre-Tertiary rocks, which sometimes occur as small, scattered inlier in the Eocene, are coloured jaspers and quartzites similar to those found in the Arakan Yoma and, like them, often intimately associated with intrusions of serpentine. From the occurrence of jasper and quartzite pebbles together with fragments of serpentine in the Eocene conglomerates, it is probable that the jasper and quartzite rocks are pre-tertiary. Their precise age is not yet known, but with them occur some pink and white porcellanic limestones which are described as similar to the Lower Cretaceous limestones of Baluchistan, presumably the Parh Limestones[4]. In some of the islands these limestones are characterised by fragments of algae, probably species of *Lithothamnium*[5].

In the Nicobar Islands, large tracts on the islands of Tilanchong and Batti Malv are occupied by rocks which may be of older Cretaceous age[6].

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[1] *Rec.*, LXVIII, 416 (1934).

[2] *Mem.*, XXI, 48, footnote 2 (1884).

[3] Gen. Rep. *Rec.*, XXXV, 48 (1907).

[4] G. H. Tipper. *Mem.*, XXXV, 205-206 (1911).

[5] E. R. Gee. *Rec.*, LIX, 223, 227 (1926).

[6] *Ibid.*, 229.

In Tilanchong they form a narrow, irregular, N.—S. ridge, reaching a height of over 1,000 feet in Maharani peak. The limestone on the west coast of this island, near Novara Bay, has yielded a *Lithothamnium* having conceptacles of the type of *L. suganum*.

PALAEOGEOGRAPHY.

Although every stage of the Cretaceous is represented in India, no locality possesses a complete sequence of the system. The fullest succession is found along the Coromandel coast, and embraces beds dating either from the Barremian (Upper Neocomian) to the Lower Aptian, and a more or less continuous series from the uppermost Albian to the top of the Danian. Elsewhere the characteristic feature of the system in India, as in South Africa and other parts of the dismembered Gondwana landmass, is the occurrence of odd stages here and there of varying age, laid down along the occasionally sub-merged fringe of severed fragments of the old continent. The Upper Albian and Cenomanian transgression seen in southern India seems to have been, in the words of Dr. Spath, "as local as were previous and later transgressional movements". It is these capricious marine transgressions which make the Cretaceous stages in India so extremely variable in nature. Examples of this are seen in the rapid lateral changes, and the great variability in thickness. The Belemnite Beds in Baluchistan, 500—600 feet of argillaceous deposits, stride no more than the middle portion of the Neocomian, while the Giumal Sandstone of Hazara and Attock, largely arenaceous as it is and here not more than 300 feet thick, appears to include horizons ranging from Upper Valanginian to Lower Albian. The Bagh beds of the Narbada valley, in some places no more than 80 feet, or less thick, contain a fauna which includes elements ranging from the Upper Albian to the Campanian, a succession which on the Coromandel coast is represented by well over 2,000 feet of sediment. It is not to be imagined that a much needed revision of many of the Cretaceous surveys will dispel such peculiarities.

A certain amount of misunderstanding has resulted from comparisons of stages of different ages, and it is important to guard against this.

The water channels which we have visualised in the Jurassic period connecting the Tethys with the Southern Ocean and as separating the island Archipelago of Lemuria as well as the island of Farsia from the African portion of the Gondwana landmass, seem to have persisted throughout the Cretaceous. Some authorities prefer the view that Lemuria was not completely separated from Africa till the early Tertiary[1]; at any rate the abundance of the flattened belemnite, *Duvalia*, in the lowest Cretaceous of Madagascar indicates a direct communication between this point and the Mediterranean by way of Portuguese East Africa, in the Valanginian deposits of which the same belemnites are found. Neither Somaliland nor the Sinaitic peninsula has yielded any Valanginian fauna, from which it may be inferred that the channels in question lay to the east of these regions; at the same time, these early Cretaceous waters may have extended sufficiently far to the west to cover portions of Tanganyika where the Valanginian, if not actually exposed, cannot be far away. The Valanginian deposits of Portuguese East Africa have in common with similar beds in the western Salt Range on the one hand the ammonite *Hoplites* (*Neocomites*) *neocomiensis*, and with the Uitenhag series of Cape Colony on the other hand fragmentary impressions of the type

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[1] According to Dr. Du Toit, it was in Middle Cretaceous times that the land-mass including Madagascar began to move away from the African mainland, with the production of the Mozambique channel.

Bochianites africanus[1]. Furthermore, the Uitenhage ammonite *Holcostephanus* (*Rogersetis*) *atherstoni* occurs in the Giumal Sandstone and Lochambel beds of the Himalaya, and a closely related form in the trans-Indus Salt Range. The resemblances between the Uitenhage and Umia faunas seems to rest largely upon the lamellibranchs, especially the Trigoniae and a species of the Uitenhage genus *Seebachia* among the Cutch ammonites ; otherwise, the ammonite faunas of the two regions are described as strikingly dissimilar, a result not unexpected in view of the greater age of the Cutch assemblage. The converse applies to the scanty lower Cretaceous faunas of the Coromandel coast which, omitting one or two Trigoniae of questionable stratigraphical value, exhibit no particular affinity with the somewhat older Uitenhage fauna ; in the Neocomian of Somaliland, however, we find counter parts of the Madras-Godavari holcodiscids, as Dr. Spath points out.

It is unfortunate that there is no extensive set of fresh-water sediments, by the contents of which it might have been possible to trace the advent of angiospermous plants. Two ferns from the Ahmednagar Sandstone are of Wealden age. The Umia beds of Cutch also belong to the lowest horizons of the period, at the latest, and contain nothing more advanced than the ferns, conifers and cycads of the previous Jurassic flora. Some silicified wood and a species of fern, *Protocyathus trichinopolitensis* Feistm., have been found in the Upper Cretaceous deposits of the East coast. Net-veined leaves and dicotyledonous wood have been collected from the Barmer Sandstone in Rajputna (? Aptian), but no angiospermous plant assemblage worthy of the name of flora is found till we come to the Lameta beds which, if not lowest Tertiary, cannot be older than uppermost Cretaceous.

Although the Uitenhage fauna of Cape Colony, S. W. Madagascar, Portuguese East Africa and Kenya, with its scarcity of belemnites and nautili cannot be said to show any intimate relationship to the Belemnite Beds of Baluchistan, the latter deposits have yielded French species of *Duvalia*, a genus characterising the Valanginian of Madagascar and Portuguese East Africa, as already noted. The affinities of the Samana Lower Cretaceous seem to be all with Europe, as are most of those of the Giumal Sandstone. The *Holcostephanus* of Kohat (Thal area) and the trans-Indus Salt Range is closely related to species found in the Crimea where, as Dr. Spath points out, the Upper Valanginian genus, *Rogersites*, also occurs ; similar species of *Holcostephanus* are also seen in the *Trigonia schwartzi* Beds of Tendaguru in Tanganyika. Amongst the magnificent development of all Cretaceous stages in Persia, the Valanginian of the south is characterised by ammonites from southern France. In Egypt, Palestine, Abyssinia and the northern parts of Somaliland, the Lower Cretaceous is represented by the Nubian Sandstone, a continental deposit very similar to the Carpathian Sandstone.

The resemblances and contrasts enumerated above present an approximate picture of the distribution of land and sea in and around the region of India during early Cretaceous times. The few Upper Neocomian or Barremian fossils of southern India are interesting in the light they throw upon the age of the Coromandel coast; it is possible that sea covered the Bay of Bengal area during the closing stages of the Jurassic, but that it did so by the end of Neocomian times is made certain by the presence of this small fauna. The waters over the Bay of Bengal area stretched northwards, perhaps over the lower portion of the Gangetic delta but falling short of the Rajmahal hills and the escarpment of the Shillong plateau ; eastward they may have covered Burma for, although the Lower Neocomian has not yet been identified in that country, the Barremian has been found in the Northern Shan States.

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[1] L. F. Spath. *Ann. S. Afr. Mus.*, XXVIII, Pt. 2, p. 135 (1930).

The probabilities are that the west coast was not yet formed, and that India remained united to Madagascar, the two regions together forming, in addition to the " Farsia " of Stefanini, another and larger island, the " Lemuria " of the zoologists. This island, we may suppose, was separated from the main bulk of Gondwanaland which still united Brazil, Africa and Australia, by the waters which now cover the Bay of Bengal and that part of the Indian Ocean between it and the east coast of Madagascar, and by the Mozambique Channel between Madagascar and Africa and its northern continuation to the Tethys. The Mozambique Channel seems to have been in existence throughout the Mesozoic era, and the analogy between the deposits of this age on the west coast of Madagascar and the east coast of Africa is striking. Later on, the large island of Lemuria seems to have broken up into an archipelago, but the close resemblance of one of the Lameta dinosaurs of India to the *Laplatasaurus madagascariensis* (Dep.) of Madagascar shows that such fragmentation is not likely to have commenced much before the Senonian epoch[1]. At the same time, the Malagassy and Indian dinosaurs, although obviously derived from the same ancestors, are not specifically identical, and the dismemberment of Lemuria may have taken place at some time sufficiently previous to the Senonian epoch to allow of the development of the specific differences noted in these Indian and Malagassy reptiles.

The central feature of Lemuria was no doubt the ancient Aravalli range, and if this continued at that time along its present alignment to the Madagascar end of the island, it would account for the long strip-like shape of the latter. In the present bathymetric configuration of the western half of the Indian Ocean floor it is possible to descry the approximate limits of this Indo-Malagassy island continent. Towards the Madagascar end we find relics of this land in the Nazareth and Saya de Malha Banks, the Seychelles and perhaps the foundations of the volcanic Amirante Islands and Mascarine Islands ; at the Indian end are the Chagos, Maldive and Laccadive Islands and Ceylon ; while midway between the two ends, connecting the Seychelles with the Maldives is a large submarine bank sufficiently marked today to prevent the ice-cold Antarctic currents which characterise the greater depths of the southern Indian Ocean from gaining access to the Arabian Sea. The unusually intimate relationship between the present-day so-called Dravidian fauna of India—found south of the Indo-Gangetic plain but not in the Malayan region—and some forms in Madagascar may well be due to the comparatively recent union between the two areas, a union which survived the marine transgressions of the Jurassic and succumbed only in late Cretaceous or more probably early Tertiary times to the disruption that accompanied the outpouring of the Deccan Trap. The Dravidian fauna includes invertebrates, batrachiana, reptiles and the Mammalian *Platacanthomys*[2] and the amount of divergence it shows from the corresponding fauna in Madagascar is no more than would be expected by independent evolution since early Tertiary times.

Dr. Spath finds that " the Neocomian transgression in the Salt Range was probably a succession of small, local events. The rich and varied ammonite fauna ever present in the seas of the equatorial belt came in with its typical elements in successive waves; it occasionally developed a local tribe that did not spread elsewhere, but such elements do not obscure the general succession of ammonite faunas, safely established "[1].

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[1] Lemoine considers the Malagassy dinosaur fauna to be Turonian-Emscherian, (Handbuch der regionalen Geologie, VII, 4, p. 11-13 (1911)).

[2] W. T. Blanford. *Phil. Trans.* Vol. 194, p. 335-436 (1901).

The same observer points out that there is no record of marine Lower Cretaceous in eastern Asia and that the Hongkong Bay depicted on Dr. Grabau's map[2] is no longer needed[3].

The Neocomian fauna of the Indian Ocean region shows sufficient affinity with that of America to demonstrate that the Tethys Sea still stretched as far west as the country around the Gulf of Mexico and the Caribbean Sea. In Mexico, beds which are either Valanginian or a little younger have supplied forms comparable to the Uitenhage species *Holcostephenus* (*Rogersites*) *atherstoni* and *H.* (*R.*) *baini*. The fauna of the Malone beds of Texas is described as similar to that of the Uitenhage of South Africa and is not without resemblances to the Umia fauna of Cutch. Colombia has furnished a series which can be correlated with the Hoplitidae beds of Spiti and whose Valanginian fauna contains species of *Rogersites* and *Bochianites* resembling Uitenhage forms. The Uitenhage fauna, however, can be more closely matched in Bolivia, Chili and especially the Argentine, and the communication between the two regions is more likely to have been direct, along the northern coast of the Southern Ocean. According to Greober, the Argentine has furnished such characteristic Uitenhage forms as *Trigonia ventricosa*, *Grammatodon jonesi*, *Holcostephanus* (*Rogersites*) *atherstoni*, *H.* (*R*). *regersi* and *H. uitenhagensis*. Chili has also yielded a *Rogersites*, and *Belemnopsis datagoniensis* may be related to *B. africana*[4]. Most of North America remained land throughout the whole of the Cretaceous period and a tract of this land separated the Tethys from the Pacific waters which in Lower Cretaceous times covered parts of California and Oregon.

In the Barremian and Aptian epochs, the Orbitolina Limestone of Gilgit, Chitral and neighbouring regions denotes a transgression by the Tethys. Another somewhat later invasion of the Cutch area, marked by the Ukra beds, took place in Aptian times and reached Persia. Along the Coromandel coast area, on the other hand, there seems to have been a recession of the sea until the end of the Albian epoch which was characterised by a fresh advance westwards. Continued connection with the Australian region was maintained *via* the Lower Cretaceous deposits of Sumatra, the Sula Islands and New Guinea. The Aptian also saw a southern extension of a previous gulf from the Boreal sea through Russia as far as the Caspian and Black Seas; by Albian times this had reached the Tethys and connected the latter with the Arctic waters. In Australia, no marine Cretaceous beds have been observed older than Aptian, an epoch which in that region was characterised by a glacial phase of no great severity.

In Albian times there was a return of the sea to the Samana-Kohat range area, and probably before the end of that epoch the encroachment of the waters covering the Bay of Bengal over the Coromandel coast initiated the deposition which persisted in this area up to and after the end of the Cretaceous period. A similar continuous deposition commenced in southern Tibet and also lasted into the

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[1] *Pal. Ind.*, New Ser., Vol. XXV. Mem. 1, p. 126 (1939).

[2] "Stratigraphy of China", Pt. II, p. 456, fig. 581 (1928).

[3] *Ann S. Afr. Mus.*, Vol. XXVIII, Pt. 2, p. 131-156 (1930).

[4] L. F, Spath. *Pal. Ind.*, New Ser., Vol. IX, Mem. 2, p. 825 (1933).

Tertiary with perhaps a short break at the commencement of the latter; this deposition was preceded a little further south along the Tibetan-Indian frontier and in Hazara and Attock by the accumulation of the Giumal Sandstone which in some places at least immediately followed the Spiti Shales. The two Giumal ammonites, *Oxytropidoceras roissyanum* and *O. acutocarinatum*, are found in the Middle Albian of Persia, accompanied by two forms from Brazil and Texas, *O. sergipense* (White) *and O. trinitense* (Gabb).

In the Albian and Turonian, and perhaps also in the intervening Cenomanian epochs, we find scanty indications of the presence of sea over what is now the west coast of Burma. The Albian of Zululand has affinities with that of Madagascar, southern India and Europe, but has no close relationship with the Angola fauna on the west coast of South Africa, which seems to have been deposited in an arm of the Tethys stretching southwards, and has marked Mediterranean characters. In its details this fauna is most closely related to that of north Africa, although the phylloceratids and lytoceratids of the latter region did not migrate so far south into the shallower water that covered the Angola area. This southerly arm of the Tethys had reached Angola in Neocomian times and persisted into the Senonian epoch as an open bay covering the Cameroons, and there is no indication of any direct connection with Madagascar and India by way of the Cape in Lower Cretaceous times. The latter conclusion seems definitely established by the fact that the faunal resemblances of the South African Lower Cretaceous are with those of Mozambique, Madagascar and India, rather than with those of Angola[1]. Nonetheless, the Angola fauna has a few species in common with Zululand, Socotra and Syria; in its Albian assemblage a Brazilian facies is seen in the presence of *Pecten* [*Neithea*] *aequicostatus*, *P.* [*N.*] *tricostatus*, *Trigonia crenulata*, *Tylostoma globosum* and *Akera gregoryi*.[2]

It is generally supposed that Africa and South America remained united as part of the old continent during the Cretaceous period, and the southern coast of this landmass seems to have afforded a means of direct communication between India and Madagascar on the one hand and the southern Andine provinces on the other. The Aptian faunas of the two regions are comparable and, in the opinion of Dr. Spath, the *Pseudophacoceras* of Zululand probably represents an immigrant Andine element. Nevertheless the Albian transgression which reached Brazil came from the north, like that of Angola, and was effected by another and larger arm of the Tethys. The genus *Knemiceras* of the Middle Albian of Persia is found in beds of the same age and of shallow-water facies in Peru. The presence in Queensland of the peculiar myloceratids (Criocones) found in the Albian of Portuguese East Africa and Madagascar is of interest as indicating the persistence of the communication with Australia[3].

The Cenomanian of India has several species in common with the Cenomanian of Tunis, Algeria, Egypt, Palestine and Syria. That of Madagascar has close relationships with the Utatur stage of southern India, as seen in the presence of such forms as *Baculites baculoides*, one or two species, of *Acanthoceras*, cosmopolitan species and varieties of *Pervinquieria*, *Diptychoceras forbesianum*, *Puzosia compressa*, *Tetragonites timotheanus*, *Gaudryceras multiplexum*, *Turrilites tuberculatus*, *Hibolites ultimus* and two or three nautiloids, many of them European types also. Above the Albian over much of northwest India there is a widespread stratigraphical gap, and the absence of the Cenomanian, and in places like Rajputana and the Salt Ranges also of the rest of the Upper Cretaceous, points to a break of appreciable size and probably to emergence and erosion; the first signs of renewed transgression are seen in the Lower Lithographic Limestone of Kohat and its possible equivalent the Parh Limestone of Baluchistan and Waziristan, all of probably Turonian age.

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[1] A.L. Du Toit. "Geology of S. Africa", 2nd Edit., 506 (1939).
[2] L.F. Spath. *Papers from Geol. Dept., Glasgow Univ.*, Vol. VI, 156 (1922).
[3] *Pal. Ind.*, New Ser., Vol. IX, Pt. 2, 829 (1933).

Thus the Cenomanian, richly developed along the margin of the continental area of southern India, is missing from the geosynclinal areas of Cutch, Sind, Baluchistan, Kohat and the Punjab; it may, however, occur in Kathiawar, and has been recognised in the eastern parts of Kashmir, and is well developed in the Hippuritic Limestone of Afghanistan and Persia. The Cenomanian from the Chisil Pass area in eastern Kashmir shows marked affinity in fauna with the Utatur and links the latter with Tripoli and Tunis. Dr. Spath calls attention to the striking resemblance between the Cenomanian *Acanthoceras* fauna of Tunis on the one hand and that of Portuguese East Africa, Zululand, Madgascar and India on the other;[1] nothing like this European fauna is to be seen in either west Africa or Brazil. The Cenomanian is represented in Australia, and by deposits in New Zealand which, in spite of their great distance away, contain no less than eleven ammonites identical with or closely allied to Utatur species.[2]

In central Asia Upper Cretaceous deposits cover a large area and hide nearly all older formations; the latter in fact appear only in isolated patches where the overlying mantle has been denuded away. In eastern Asia the Cretaceous is mostly of a continental facies, but in Yesso and Saghalin there is a well marked Indian type of Upper Cretaceous.[3] Connecting part of the sequence with the Utatur stage are many allied and several identical species, such as *Gaudryceras sacya*, *G. multiplexum*, *Phylloceras velledae*, *P. whiteavesi*, *Acanthoceras rotomagense* var. *asiatica*, *Tetragonites timotheanus*, *Puzosia crebrisulcata*, and *Cymatoceras virgatum*. The *Acanthoceras* horizon of the Utaturs is identifiable in one of the Cretaceous areas of Brazil, and Utatur forms are found half the circumference of the globe away, in California and Queen Charlotte Island in the northeastern Pacific; from California come *Pervinquieria inflata*, *Lytoceras mahadevi*, *Gaudryceras sacya*, *Tetragonites timotheanus* and *Acanthoceras turneri*; from Queen Charlotte Island *Lytoceras mahadevi*, *Gaudryceras sacya*, *Tetragonites timotheanus*, *Pervinquieria inflata* and *Hamites glaber*. In the Himalaya the Upper Cretaceous is represented by the Flysch and the Chikkim series.

The Turonian of Persia and Afghanistan is rich in massive rudistid limestone. Rudistids occur in Baluchistan, but the rarity of these peculiar and characteristic lamellibranchs in the Indian region, except in the extreme west, is remarkable when it is remembered that members of this family are as plentiful in parts of Asia, such as Asia Minor, Armenia, Persia, Afghanistan, Turkistan and Tibet, as they are in Europe or America. Kühn has described the distribution of the rudistidae in Asia[4] and suggests that the centre of evolution lay in the south European portion of the Tethys; east of the Indian frontier they appear to become scarce. Nonetheless, rudistid limestones have been found in the Malay Archipelago, and species of the genera *Radiolites* and *Sphaerulites* have been described therefrom. In Japan rudistids are recorded from the Lower Cretaceous.

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[1] *Papers from Geol. Deptt., Glasgow Univ.*, Vol. VI, 158 (1922).
[2] P. Marshall. *Trans. New Zeal. Inst.*, Vol. LVI, 194 (1926).
[3] F. Kossmat. *Rec.*, XXVIII, 48 (1895).
[4] *Rec.*, LXVI, 169-174 (1932).

On the west side of the Indian " island ", from the broad channel which united the Tethys with the Southern Ocean, a transitory gulf stretched up the Narbada valley from Kathiawar. The initiation of this gulf may have taken place as early as Upper Albian times, and the ammonites found among its sediments prove definitely that it was in existence in Turonian times ; there are no indications that it survived the Senonian, at the close of which epoch it seems to have been replaced by a river valley. Contrary to earlier opinion, the Bagh beds of the Narbada valley do show some resemblances to the south Indian faunas and rather more to the Trichinopoly and Ariyalur than to the Utatur. One of the faunas at Yesso and Saghalin shows a connection with the Trichinopoly fauna of southern India in the presence of forms allied to *Pachydiscus peramplus*. It is interesting also to record the presence in New Zealand of four ammonites identical with or closely related to Trichinopoly species. There is evidence of the Turonian sea over the Arakan coast of Burma. The Turonian of Nigeria and the Cameroons suggests by its fauna direct marine communication not only with Tunis but also with Brazil ; the eastern parts of Africa are devoid of ammonite-bearing Turonian deposits. During the latter half of the Cretaceous period the central portions of Australia suffered a recrudescence of the early Gondwana glacial conditions.[2]

In Upper Senonian times the waters covering the present Bay of Bengal swept up to the Shillong plateau, where they left behind a fossil fauna, 42 per cent. of which is found in the Ariyalur stage of the Coromandel coast ; eastwards they have left their traces in the Arakan Yoma and Pakokku district of Burma. On the other side of the Indian land area, an extensive encroachment had taken place during the Turonian epoch over Baluchistan, Sind, the southwest Punjab, Kohat and Waziristan, by the sea which remained there till well into the Tertiary era. Ten per cent. of the Hemipneustes Beds and Olive Shale fauna of Baluchistan is found in the Ariyalur stage of southern India ; *Hemipneustes*, which characterises the former, is the typical echinoid of the Chalk of Maestricht, and the two Baluchistan formations, whatever their mutual relations may be, probably include a part of the Maestrichtian. The Cretaceous of southern Tibet includes stages with several fossils identical with forms in the Hemipneustes Beds and Olive Shales (" *Cardita subcomplanata* beds ") of Baluchistan and their Persian equivalents. These Tibetan faunas also show distinct affinities with those of the Coromandel coast and Assam, but it is in the fauna collected from the neighbourhood of the Karakoram Pass that the latter are more closely paralleled ; the Kashmir assemblage is in fact strikingly similar to the Ariyalur on the one side, and to the Mediterranean especially the north African faunas on the other. These marked resemblances may be interpreted as signifying either a sea communication between all four regions round the northeast corner of the old Lemurian island, or else a break-up of Lemuria with the collapse of the India-Madagascar land connection. The second alternative receives some support from the presence of Indo-Pacific Maestrichtian species in western Persia, but the first affords a more credible

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[1] P. Marshall. *Trans. New Zeal. Inst.*, Vol. LVI, 196 (1926.)

[2] W.G. Woolnough and T.W.E. David. *Q. J. G. S.*, Vol. LXXXII, 349 (1926).

[3] C.F. Parona. *Att. R. Lincei*, Ser. 5, Vol. XXVI.2 SEM., 53-57 (1917).

explanation of the similarities between the Upper Cretaceous reptiles of India and Madagascar[1].

Turning to South Africa, we find faunas in Natal and Pondoland showing affinities with the Ariyalur and especially with the Valudayur sub-stage. The Upper Cretaceous fauna of Portuguese East Africa is also related to that of southern India. More extensive collecting and a more careful comparison have shown that the resemblances between the faunas of southern India and South Africa are not quite so intimate as they were at first supposed to be, and are due in the main to a similar assemblage of genera and the occurrence of a number of allied species. Out of about 100 species of lamellibranchs and gastropods in the Pondoland fauna only 14 are found in southern India, and some of these, such as *Pecten quinquecostatus*, *Eriphyla lenticularis*, etc., are widespread forms; on the other hand a large proportion of the southeast African fauna is peculiar to that region, so much so that Pondoland, Natal, Zululand and possibly Portuguese East Africa are regarded by some as forming a distinct Upper Cretaceous faunal province in the Indo-Pacific region[2]. The Upper Cretaceous of Madagascar is poor in Ammonoidea and has faunal resemblances to southern India rather than to southeast Africa; common to Madagascar and southern India are a large number of species. The presence in the Upper Cretaceous of both Madagascar and southern India of *Potamides* points to the presence of estuarine sediments. The Indo-Malagassy Upper Cretaceous fauna shows closest relations with the faunas of the Pacific and Antarctic regions; the most characteristic element of this vast Indo-Pacific province is *Kossmaticeras*, a genus found in South Africa as well as in Madagascar and India[3]. The Natal beds contain the following Ariyalur species: *Hauericeras gardeni*, *H. remda*, *Gaudryceras kayei*, *Holcodiscus indicus*, *Pugnellus uncatus*, *Solariella radiatula*, *Pollia pondicherriensis* and *Turritella breantiana*. In Zululand are found such forms as *Peroniceras* of. *dravidicum*, *Kossmaticeras* [*Madrasites*] *bhavani* and the Utatur *Nautilus* (? *Cymatoceras*) cf. *justus*; half the ammonites in the Umkwelane fauna of Zululand consist of *Baculites*. Many of the Japanese species of *Pachydiscus* are closely allied to or identical with Ariyalur forms[4]; from Yesso come *Pachydiscus ariyalurensis*, *Hauericeras gardeni* and *Hamites largesulcatus*. The Upper Cretaceous of Borneo abounds in specimens of *Nerinea* and contains Ariyalur fossils such as *Hercoglossa trichinopolitensis*, *Exogyra ostracina* and the widespread long-ranged *Terebratula biplicata*. The affinities of the Upper Senonian of Angola are with both north Africa and Pondoland.

Ariyalur types have been recognised in widespread regions, and the Indian Upper Cretaceous would appear to form a link between that of the Pacific and that of the Atlantic areas. In the Upper Chico formation of California we find *Pachydiscus newberryanus* Gabb, a species very close to *P. otacodensis* (Stol.), while Vancouver has yielded several types close to or identical with Ariyalur species, such as *Pseudophyllites indra* (Forb.), *Pachydiscus newberryanus* Gabb, *P. otacodensis* (Stol.), P. aff. *tweenianus* (Stol.), *Heteroceras cooperi* Meek, *Baculites occidentalis* Meek, a form close to the Indian *B. vagina* Forb., *Hauericeras gardeni* Baily, *Gaudryceras jukesi* (? Sharpe) which is nearly identical with *G. kayei* (Forb.), and *Hamites obstructus*, a close relative of *H. rugatus* Forb. in the Ariyalurs. In South

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[1] L. M. Davies. *Proc. 6th. Pac. Sci. Congr.*, 1939, p. 416

[2] *Trans. Roy. Soc. S. Afr.*, Vol. X, 114 (1922).

[3] L.F. Spath. *Ann. S. Afr. Mus.*, Vol. XII, p. 272 (1921).

[4] F. Kossmat. *Rec.*, XXVIII, 48 (1895).

America, Chile has furnished *Baculites vagina* Forb., *Phylloceras surya* (Forb.), *Gaudryceras kayei* (Forb.), *G. varuna* (Forb.) and *Pugnellus uncatus* (Forb.). A Senonian transgression occurred in Patagonia.

In southeast Africa there is a similar mixture of Atlantic and Pacific ammonoids. South Africa seems to have derived the Indo-Pacific elements of its fauna directly from India along the eastern coasts of the Lemurian islands and not by way of the ocean which included the south Pacific ; this deduction is made by Dr. P. Marshall mainly on account of the absence of Atlantic ammonite types from the faunas of the Antarctic Seymour Islands and New Zealand. The faunas of Pondoland and Seymour Island have no lamellibranchs or gastropods in common, but 22 per cent. of the ammonites from the former are represented by identical or closely allied species in New Zealand. No less than 34 per cent. of the Ariyalur ammonites are found as either identical or related species in the Upper Senonian of New Zealand ; this resemblance between two such distant faunas is so marked as to suggest, in the opinion of Dr. Marshall, a more or less continuous coast-line connecting the two areas, especially in view of the fact that some of the allied forms, such as the species of *Ptychoceras*, belong to genera which have limited powers of dispersion[1]. Species of *Baculites, Kossmaticeras* and *Gaudryceras* also illustrate the close affinity between the Senonian faunas of New Zealand and Southern India. These faunas are also intimately related to a similar Campanian fauna in Seymour Island ; here the affinity is seen not only in the ammonites but also in molluscan species of *Amberleya* and *Thyasira* very similar to species found in New Zealand and with them specimens of *Inoceramus concentricus*.

The Danian, Palaeocene and Eocene appear to be unrepresented by marine strata in Australia, which during this long interval was reduced to an almost perfect peneplain. During Upper Cretaceous times, South Africa, Madagascar, southern India, the Antarctic region (Seymour Island), South Patagonia, Borneo, Japan, Saghalin, Vancouver, California, New Caledonia, Chile and New Zealand, all seem to have belonged to a single extensive biogeographical province. The extremely close resemblance of the *Kossmaticeras* beds of Pondoland with those of Antarctica, south Patagonia, Chile and New Zealand is taken as an indication that Africa was still united to Brazil in Upper Senonian times.

The Niniyur beds of southern India have their counterpart in the Danian of Portuguese East Africa, and the equivalent *Cardita beaumonti* fauna of Baluchistan, Sind and the Arakan Yoma has been recognised in Persia, the Sudan and the Pyrenees. It is interesting to find in beds of the same age in Brazil a variety of *Pyrazus pernanus* (White), a gastropod which in the Niniyur Beds of Southern India is associated with a variety of *Hercoglossa danica* (Schloth.) ; the Brazilian beds are devoid of cephalopods. At the end of the Cretaceous period the central and northern parts of Persia were elevated to form land which has persisted to the present day ; the southern part of this country remained under marine conditions till a much later date and the Persian coast of Cretaceous times lay much farther north than it lies today. Before the end of the period, there are indications that the Himalayan geosyncline became closed at its eastern end and India permanently united with the Angara landmass by way of the Assam promontory. The volcanic disturbances which began probably before the end of the Cretaceous period but reached their maximum in early Tertiary times are described in chapter XXVII.

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[1] *Trans. New Zeal. Inst.*, Vol. LVI, 295 (1926).

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CORRIGENDA

A Manual of the Geology of India and Burma, Vol. II, Third Edition,
E. H. Pascoe.

Page No.	Paragraph No.	Line No.	For	Read
485	2	29	cdaracter	character
487	3	1	principa	principal
487	footnote	1	upperc	upper
494	3	7	tye	the
501	7	1	ths	the
505	5	5	difficdlt	difficult
527	3	10	sufrace	surface
553	5	5	separato	separate
570	4	1	ba ed	based
587	4	5	interoalations	intercalations
587	4	7	algar	algal
589	1	16/17	Handwara	Hundwara
597	1	10	argiaceous	argillaceous
601	2	16	representod	represented
602	4	13	of	cf.
603	last	last	Sinurian	Silurian
620	2	12	*Echinoencrines*	*Echinoencrinus*
620	2	24	form	from
628	2	14	iden al	identical
629	3	last	*Illoenus*	*Illaenus*
629	3	last	*pvnctulosus*	*punctulosus*
635	1	8	satge	stage
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651	2	14	accoun	account
666	1	5	Lamcllibranchiata	Lamellibranchiata
667	3	last	young	younger
669	footnote	1	4	i
670	4	21	rıd	red

CORRIGENDA—contd.

Page No.	Paragraph No.	Line No.	For	Read
670	4	22	Conglomerates	Conglomerates,
680	3	1	oppos	opposite
681	2	2	destrovcd	destroyed
681	2	7/8	foraminifcra	foraminifera
682	1	9	pproached	approached
683	4	2	pateau	plateau
684	..	last	*Actino t ma*	*Actinostroma*
697	footnote	1	T. A. D. La Touche	T. H. D. La Touche
700	..	41	*Prodaclus*	*Productus*
710	..	38	*crientalis*	*orientalis*
739	6	2	ara	are
739	6	2	desi nated	designated
762	..	5	Actinezoa	Actinozoa
773	..	23	Urala	Urals
774	..	..	Page 77	Page 774
780	3	14	gacial	glacial
781	..	..	Page 78	Page 781
784	..	..	Page 84	Page 784
789	5	2	Agglomeratie	Agglomeratic
792	6	1	Salte	Slate
803	3	4	zancs	zones
805	4	4	Plani	Blaini
807	1	9	*S. muaakheylensis*	*S. musakheylensis*
807	footnote	1	*Spririfer*	*Spirifer*
809	1	13	fold ng	folding
809	3	2	vley	valley
811	2	12	deformatiou	deformation
812	4	13	metmorphosing	metamorphosing
813	1	17	OLgocene	Oligocene
818	1	2/3	recrysallised	recrystallised
818	1	6	Slit-stone	silt-stone

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Page No.	Paragraph No.	Line No.	For	Read
819	4	5	rhicker	thicker
825	6	1	intrc-bedded	interbedded
825	6	3	oolirte	oolitic
828	1	12	Blain	Blaini
834	2	1	Periodotite	Peridotite
835	1	3	Sugests	Suggests
857	5	5	Eo-Tries	Eo-trias
861	2nd	Col. (vert.)	Aniisen	Anisian
862	6th	Col. (Horz.)	*Hedenstroemisa*	*Hedenstroemia*
866	3	20	indentified	identified
867	3	..	Mushelkalk	Muschelkalk
870	..	23	Mojsisoivcs	Mojsisovics
873	4	4	fannistic	faunistic
874	2	3	*Holobia*	*Halobia*
886	..	1	Cepholopoda	Cephalopoda
888	3	13	*Pscudomonotis*	*Pseudomonotis*
888	footnote	..	Brockets	Brackets
891	4	5	carute	carnic
898	2	5	Othoclase	Orthoclase
914	1	3	latte	latter
920	3	5	tra ts	tracts
921	2	15/16	di turlance	disturbance
921	2	16	outsside	outside
921	3	10	somctimes	sometimes
922	footnote	..	Crookshark	Crookshank
923	footnote	..	Ginkgoiter	Ginkgoites
928	2	2	tmall	small
928	2	7	Tilite	Tillite
934	..	1	Karhorbari	Karharbari
937	..	3	Trai	Trias
939	..	1	(L) *Foltzia*	*Voltzia*

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939	..	1	(R) Antaretica	Antarctica
939	..	14	(L) *Tnniopteris*	*Taeniopteris*
941	4	6	Talhcer	Talcher
950	4	6	of	or
951	footnote	4	incontive	incentive
955	2	17	undertying	underlying
959	1	6/7	Tnbroken	unbroken
961	3	2	loss	less
963	footnote	3	5	3
963	5	last	Deoli	Deoli[3]
968	1	3	fugure	figure
969	footnote	4	Roptilia	Reptilia
972	2	18	shewing	showing
972	footnote	8	form	from
979	4	11	*Arauearites*	*Araucarites*
979	5	19	aut	and
979	5	26	*Paleeozania*	*Palaeozamia*
993	3	3	*Arqucarites*	*Araucarites*
994	4	last	Sahui	Sahni
1000	4	13	*Nilssomia*	*Nilssonia*
1004	footnote	3	*Area*	*Arca*
1035	1	10	coaifield	coalfield
1036	4	2	3	30
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1040	4	9	or	for
1048	3	12	Ranigan	Raniganj
1052	2	5	Northen	Northern
1061	3	last	*mangaliensis*	*mangliensis*
1067	5	1	Colapilli	Golapilli
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1076	2	8/9	northeru	northern

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Page No.	Paragraph No.	Line No.	For	Read
1077	3	..	au	an
1077	3	..	in the second place and by its labyrinthodonts	in the second place by its labyrinthodonts
1100	3	12	pluvial	fluvial
1122	4	10	Norie	Noric
1129	1	6	yellaw	yellow
1132	..	1	Cophalopoda	Cephalopoda
1132	4	25	*irregnlaris*	*irregularis*
1144	footnote	1	*Paralleledon*	*Parallelodon*
1149	..	40	*Preudovirguloides*	*Pseudovirguloides*
1151	2	33	Perisphinetidae	Perisphinctidae
1153	2	14	of.	cf.
1153	2	18	Perishphinetidae	Perisphinctidae
1159	1	9	prisphinctid	perisphinctid
1160	2	2	*Pleurotomaria. Mytilus*	*Pleurotomaria, Mytilus*
1165	3	8	shear	sheer
1182	4	1	Karakoram	Karakoram[2]
1189	4	4	oj whit	or white
1193	1	1	lic	lie
1201	footnote	..	2	2 in page 1202
1207	3	17/18	holc-crystalline	holo-crystalline
1237	..	49	Douoille's	Douville's
1258	1	last	algala	algal
1273	2	4	cnalk	chalk
1276	1	3	Searcely	Scarcely
1276	2	5	ayyear	appear
1277	..	(L) 12	*Bhynchonella*	*Rhynchonella*
1278	..	(R) 23	S. A3rics	S. Africa
1280	2	8	thoughr	thought
1280	4	12	Ahhough	Although
1280	4	13	rhe	the
1280	4	14	rhe	the
1280	4	14/15	correlarion	correlation
1288	2	4	mere	more
1291	4	last	*Trigona*	*Trigonia*

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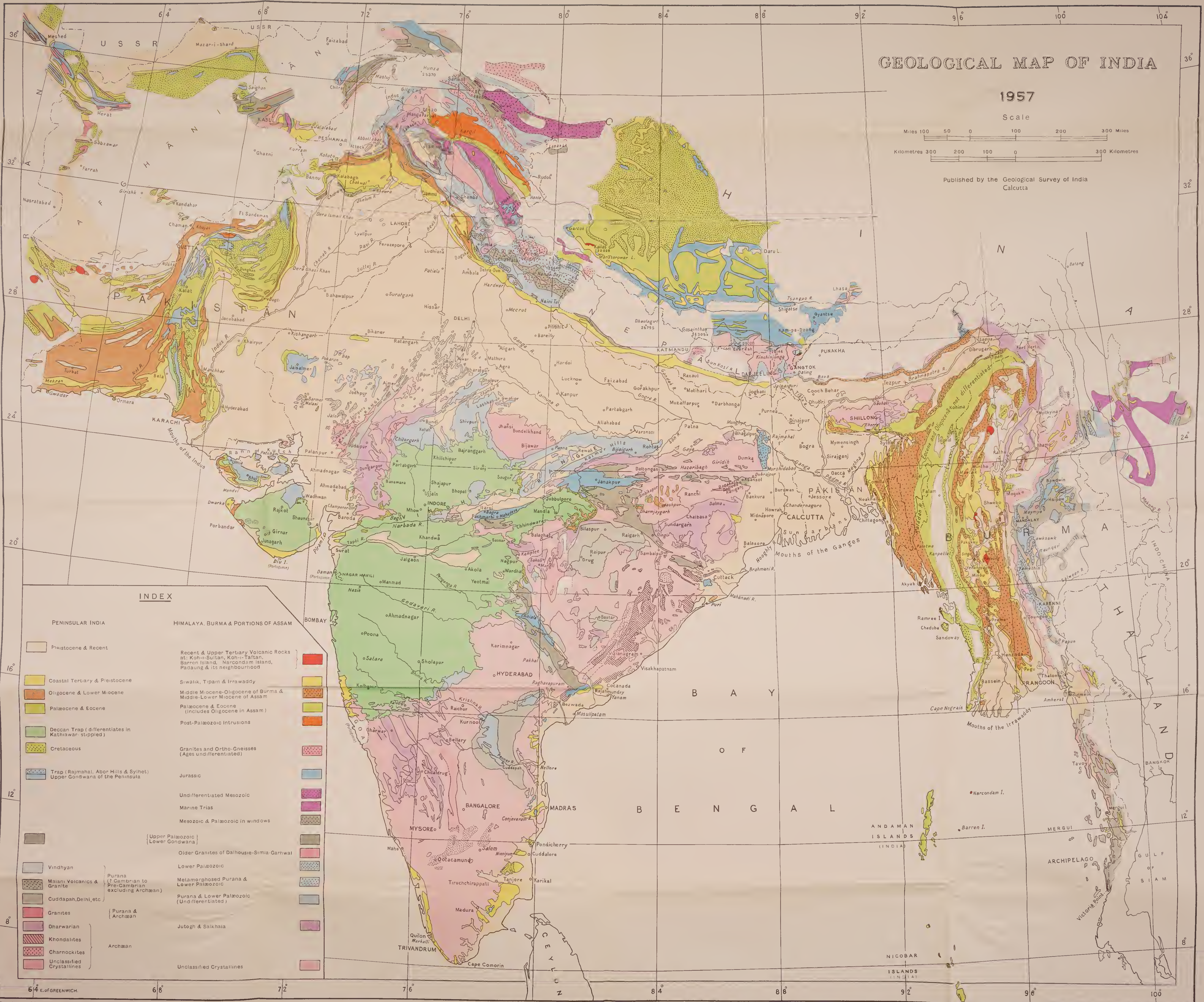
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